Illinois Research

Agricultural Experiment Station
Spring/Summer 1989

Marketing Illinois Products

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 31, Numbers 1/2

The Cover

Community farmers' markets are only one of several direct-marketing opportunities available to local growers.

"At a time unlike any in the past, we must envision the future."

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W.R. "Reg" Gomes

In March, W.R. "Reg" Gomes was named dean of the University of Illinois College of Agriculture following the departure of John R. Campbell, who assumed the presidency of Oklahoma State University. Dean Gomes brings to this position an exemplary record in both research and administration.

Gomes came to the University of Illinois in 1981 to head the Department of Dairy Science. Four years later, he became the head of the new Department of Animal Sciences. A distinguished scholar, he has coedited five books and authored or coauthored more than a hundred papers, articles, and book chapters.

During his tenure as a faculty member at The Ohio State University from 1965 to 1981, Gomes served in overseas posts twice: in 1974, as a Fulbright-Hays Distinguished Traveling Professor at Zagreb University in Yugoslavia and in 1980, as a visiting fellow and visiting professor at Kyoto University in Japan.

The grandson of Portugese immigrants, he earned his undergraduate degree in dairy science in 1960 at California Polytechnic State University, where he worked on the student dairy farm to meet college expenses. He specialized in animal physiology and endocrinology for both his Master's degree, received in 1962 from Washington State University, and his doctoral degree, received in 1965 from Purdue University.

As dean and as head of the Department of Animal Sciences, he has played a key role in developing several academic and building programs. For example, he was involved in the importation of Chinese swine and in obtaining funds for building the facility in which the pigs will be housed and studied.

Gomes strongly believes that the College of Agriculture has an essential mission to fulfill: "If we are to prosper in a changing world, it is vital that the importance of modern agriculture in the everyday lives of all citizens becomes part of the general educational process. It is up to the College to see that such education happens." □

Illinois Research

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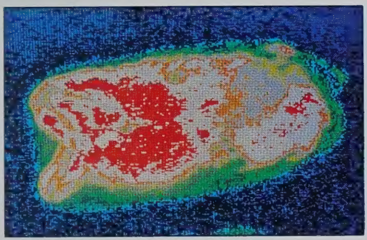
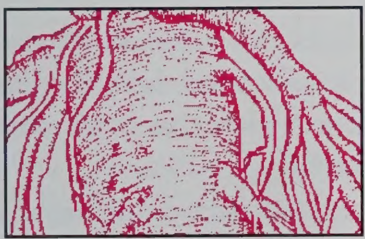


1989 – Directions – 1999

Serving Customers and Clients — the Key to Meeting Competition Effectively

Dr. Donald A. Holt, director, Illinois Agricultural Experiment Station

In his book, *Thriving on Chaos,* Tom Peters observes that successful private firms become "obsessed" with serving their customers and clients. According to this guru of business management, this degree of commitment is required to survive the stiff competition of the global marketplace.

Consumers of agricultural products are becoming more demanding. They are insisting on high-quality, safe, and affordable agricultural products. When they select among alternative products, they send important messages to producers, processors, and marketers of those products. This issue of *Illinois Research* reports how these groups can listen to, interpret, and respond to those messages.

Since science transformed agriculture a little over a century ago, agricultural production has increased to meet the growing demand for agricultural products. There is evidence, however, that agriculture is maturing as an industry.

In a mature industry, production capacity equals or exceeds the effective demand for products, and competition plays an important role in determining who will and who will not produce for the market. When supplies of products are ample, consumers can become much more discriminating in terms of quality and price. Under those conditions, the producers' emphasis must shift from finding markets for what is produced to producing what the market wants.

Marketing those products, moreover, is a complex activity, involving all components of a production and marketing system. Although advertising is important, it is only one part of marketing. Strategies to expand, penetrate, and capture markets may involve changes in research and development, production, processing, distribution, advertising and promotion, retailing, and modes of utilization. Successful strategies call for close coordination of technological changes in each of these important activities.

But in agriculture, the groups who produce, process, distribute, and market agricultural products are usually separated in space and time. Frequently, they are not within the same business structure. Communication among these groups is often difficult. One of the great marketing challenges is to improve communication and coordination within the entire agricultural infrastructure so that all agricultural groups can work together to respond more quickly and effectively to changes in demand for agricultural products. It is no longer possible for any of these groups to "go it alone."

In the past, people have expressed concern that the competitive nature of a capitalistic system may result in the exploitation of consumers and workers. Certainly, however, there must be something basically good about a system in which people compete to see who can serve the consumer most effectively.

In modern capitalism, those who serve consumers most effectively are rewarded with higher incomes, greater continuity of employment, and, hopefully, the satisfaction of having done a job particularly well. For those who want to receive these rewards, the greater the competition, the greater the challenge to identify consumers' needs and desires precisely and to deliver affordable products, closely tailored to those needs and desires.

Donald A. Holt, director, Illinois Agricultural Experiment Station

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produce
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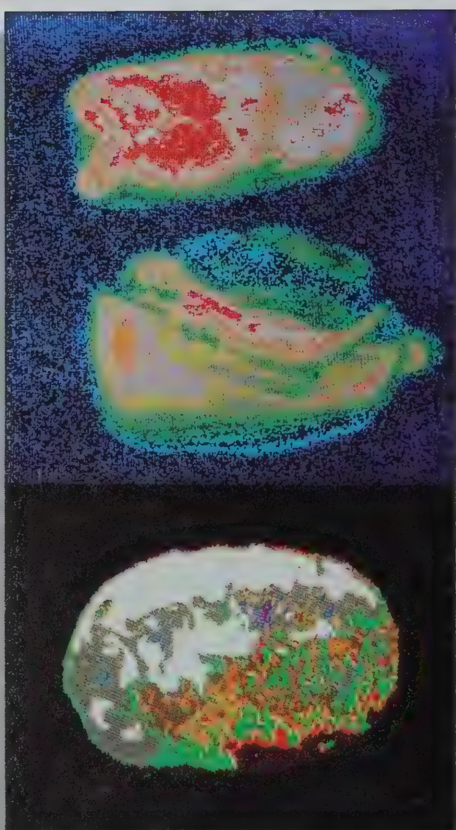
Strategies for Marketing Agricultural Products

Lowell D. Hill



Computer images of corn kernels and a soybean showing mold damage.

Marketing has often been defined simply as selling and delivering products to processors or consumers, but this definition is inadequate in the highly competitive markets for most agricultural products. It focuses attention on satisfying the producers' need to move their products rather than on satisfying the needs and preferences of consumers.

Successful marketing requires identifying the buyers' needs and producing commodities designed to meet them. According to this view of marketing, producers must have their final consumers' needs in mind from the moment they plan production and select the variety to plant until they have delivered the final product. Successful marketing of agricultural products starts with genetic research and ends with postdelivery, service-oriented, follow-up communications with final consumers at home and abroad.

How can such a broad program be implemented? For most agricultural producers, this marketing strategy requires group action involving producer organizations, state and national government agencies, and university research to supplement the actions of individuals.

Identifying consumer preferences

In most instances, individual farmers are not in a position to survey the needs and preferences of final consumers. Farmers do occasionally have the opportunity to talk with domestic and foreign buyers about their preferences and problems related to an agricultural product. This information may influence future decisions. But for most agricultural products, farmers do not deal directly with final consumers and must market their raw products through local marketing or processing firms.

A systematic evaluation of consumer and processor preferences, therefore, requires the joint efforts of many farmers, who often utilize trade associations and community groups with contributed funds for market promotion. The various checkoff programs listed in the article by Richard A. Vogen in this issue are only one of many examples. University research, like the work on soybean characteristics desired by processors in the export market described in this issue by Karen Bender, can also provide information about domestic and foreign buyers' preferences. Farmers can use this information to guide their variety selections, handling methods, and market contracts.

Corn kernels showing internal stress cracks created by rapid drying.

Accommodating buyers' preferences

Once the focus has been shifted from finding a market for what is produced to producing products the market desires, many opportunities emerge for improving the profitability of Illinois agriculture. Changes in the variety of corn and soybeans selected can alter physical and chemical properties to meet the needs of processors. Steven R. Eckhoff, Marvin R. Paulsen, and J. Bruce Litchfield note in their article, for instance, that hard endosperm varieties of corn are more profitable for dry millers. Color, size, and packaging are important to consumers of fresh fruits and vegetables.

Price stability and reduced risk of price changes are important to many foreign buyers of grain and livestock products. U.S. producers and marketing firms shift some of these risks to other people by using organized futures markets. The functions and importance of commodity futures and options markets are discussed in greater detail in this issue by Philip Garcia, Raymond M. Leuthold, and Robert J. Hauser.

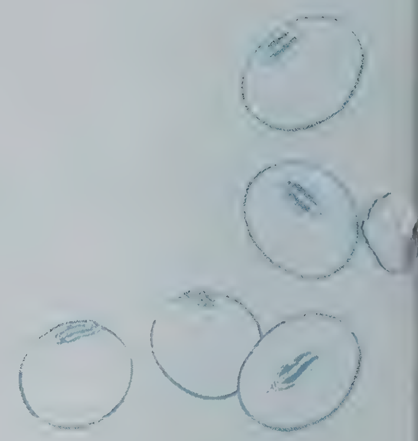
The opportunity to shift risk does not exist in many countries and is not available for all U.S. commodities, such as those sold in the thin markets described by Sarahelen R. Thompson in her article. Financial risks sellers and buyers absorb can add to the cost of marketing.

Strategies for marketing should consider this additional cost, precede production, and include the identification of

After early morning deliveries have been made, retailers' trucks line up to pick up fresh produce daily at the South Water Market in Chicago (top).

This broker on the phone at the South Water Market is purchasing produce for quality-conscious consumers (middle).

Leafy green vegetables from Plainfield, Illinois, on display at the South Water Market (bottom).



domestic and export specialized markets. Contracts with buyers are becoming more common even in commodities, such as corn and soybeans. They assure the producers of a market and identify the product characteristics that will bring the highest price.

As Barbara P. Klein points out in her article on trends for marketing fresh meat, buyers' tastes and preferences are subject to change. Noreen Frye describes the dramatic impact on sales and consumer attitudes of several very successful advertising campaigns of the pork industry.

Promotion and advertising may alter preferences, but they also provide buyers with more information for making choices among alternative products and qualities. Producers, as Michael A. Hudson reports in this issue, should and do take an active role in product promotion, but they also need to choose advertising strategies that pay more than they cost.

The relationships between raw product characteristics and the quantity and quality of processed products are not always known. This information is essential if processors are to make the best choice of quality for their purposes.

Researchers at the University of Illinois are studying food processing to provide this information to domestic and foreign buyers. For example, specialists investigating the manufacture of starch and sugar from corn have identified that reducing the amount of heat used in drying high-moisture corn will increase the yield of starch. Other researchers have examined the chemical composition of soybean oil and the soybean's genetic potential for being chemically altered to meet specifications for certain specialized industrial uses.

Finding a market niche

With the emphasis on the customer's preferences, important differences soon become obvious. Cultural differences in food preferences are generally recognized but not always given consideration, especially in the export market.

U.S. exporting firms often fail to recognize that what U.S. consumers find appealing in a product's form, consistency, and color may not sell well in the Orient. Japan has recently purchased a beef feedlot in the United States because importers were looking for a more highly marbled beef than they were receiving from U.S. exporters.

Similarly, the preference of Italian poultry feeders for dark yellow skins on broilers induced premiums for Argentina corn for many years.

More significant differences in preferences are those related to the processing industries. The "best" chemical and physical characteristics of corn and soybeans depend on the industry. Hard endosperm corn is desirable for dry milling firms producing corn flakes, but it will increase the processing costs in wet milling, where starch and corn sweeteners are extracted through a steeping process. Processors in Denmark are requesting high protein soybeans for the manufacture of protein extenders; oil crushers in Japan are asking for higher oil in soybeans even if it means lower protein content. Korean tofu producers want large beans; Japanese producers of bean sprouts want small ones. For processors, all corn and all soybeans are not alike.

Even for traditional crops like corn and soybeans, effective marketing requires that producers identify the market niche where they can best supply products with the desired characteristics to domestic and foreign consumers. J.W. Courter and David J. Williams discuss this and other essential considerations for marketing horticultural products.

Many small-volume markets are seeking reliable suppliers of agricultural products with unique characteristics. Opportunities often exist for increasing sales through further processing or otherwise altering the product, as Gene E. Campbell and Gary L. Rolfe demonstrate in their article on opportunities for marketing forest products. Alternative market outlets, such as the pick-your-own ventures described by J.W. Courter, present additional opportunities.

Marketing and production decisions must be integrated into a unified strategy in order to direct needed resources and management skills into these markets. By responding quickly to new market opportunities, smaller companies can effectively compete with multinational corporations even in export markets.

Lowell D. Hill, professor of agricultural marketing, Department of Agricultural Economics

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Soybean Quality Characteristics: What's in a Grade?

Karen L. Bender

U.S. standards for soybeans, first issued as tentative grades in 1924 and brought under the United States Grain Standards Act in 1940, emphasized the physical properties considered important in marketing soybeans. These grades have changed relatively little since they were published in 1924.

Researchers at the University of Illinois College of Agriculture are investigating the need to change the quality characteristics that should be measured in grades and standards to provide the information desired by processors in the export market. Because soybean grades should provide information about value to soybean processors, it is important that these grades reflect their preferences.

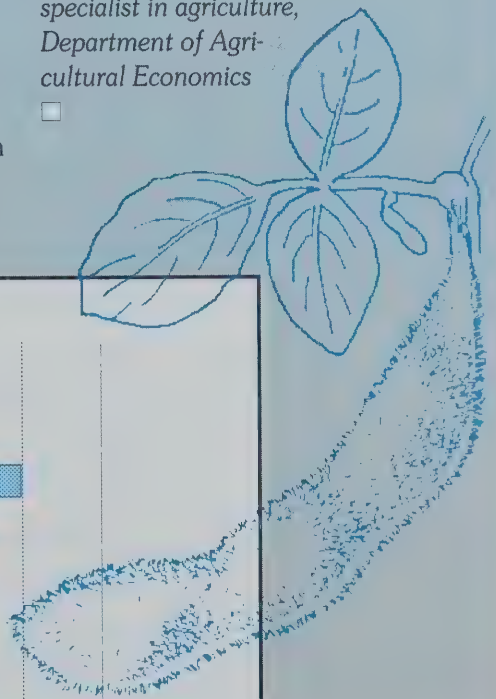
A study conducted jointly by the University of Illinois Department of Agricultural Economics and the Institut de Gestion Internationale Agro-Alimentaire, based in France, used a mail survey and personal interviews to determine which soybean product characteristics were sufficiently important to processors in Western Europe that they were measured on every shipment when received at the plant. It was assumed that measurement would only take place if the information gained was more valuable than the actual cost of measurement. In all, 25 surveys were obtained. Of these, 23 were determined to have enough detailed information to be usable in calculations. Over 80 percent of these processors measured moisture, oil, and foreign materials in every delivery as shown in the accompanying figure.

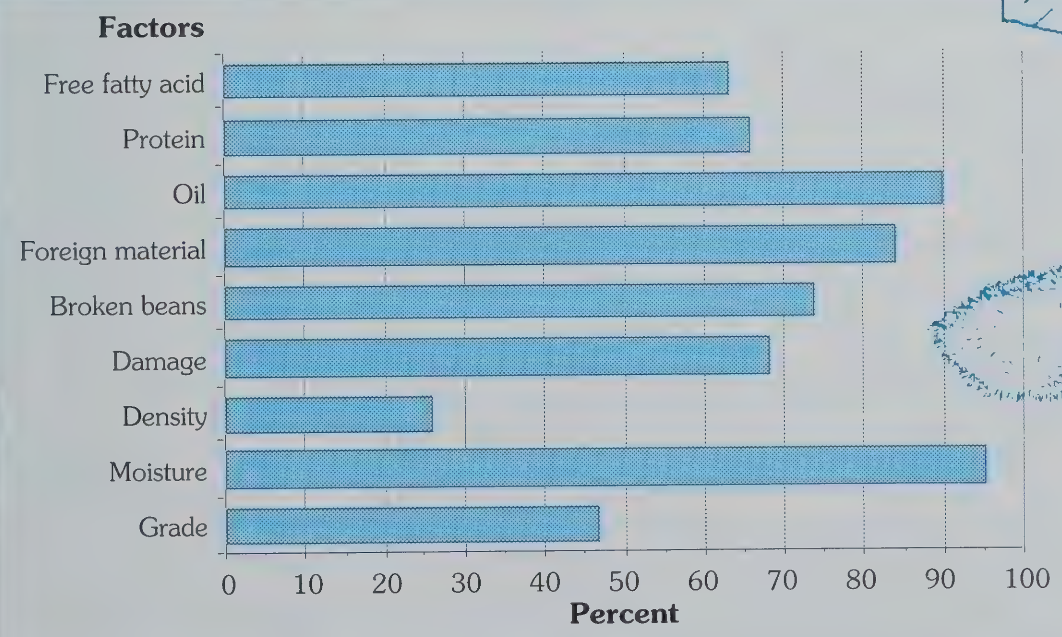
In a second study covering a broader range of countries, processors were asked to rank the importance of quality characteristics on a scale of 1 to 7. This study was conducted in cooperation with the American Soybean Association and the Office of Technology Assessment. Of the 34 usable surveys, the average rankings on protein, moisture, and oil were 6.8; on free fatty acid, 6.6; and on foreign material, 6.5. Only two of the soybean characteristics that were ranked above 6.5 — moisture and foreign material — are included in U.S. grades. Other grade factors — test weights and splits — were ranked 5.0 and 6.0, respectively.

Identifying important quality characteristics provides a basis for organizing a marketing system to deliver what the buyers want. The United States has achieved some success in providing characteristics found desirable in both studies. In comparison, Brazil and Argentina frequently furnish oil and protein content data but rarely give grade information because it is not generally requested.

A continuing challenge to researchers, therefore, is identifying processors' quality preferences because these preferences provide a basis for changing U.S. grades to include economically important characteristics. Reporting this information on export certificates and using it in the market channel will increase market efficiency.

Karen L. Bender, visiting research specialist in agriculture, Department of Agricultural Economics





Quality factors measured in every delivery by processors in the European Economic Community

Processing the Right Corn

Steven R. Eckhoff,
Marvin R. Paulsen,
and J. Bruce Litchfield

Korean wet and dry corn milling facility.

About 1.5 billion bushels of corn a year are processed into food or industrial products by wet or dry milling. Wet corn milling produces such products as starch, high fructose corn syrup, corn oil, and ethanol. Dry corn milling yields corn oil, corn flour, corn meal, and corn grits for use in flaking into breakfast cereals, brewing into alcoholic beverages, and extrusion into corn-based snacks.

Achieving efficient mill operation and an optimal yield of products requires processing corn with the right characteristics. Current grade factors, however, do not reflect the different quality characteristics that are needed in corn milling.

Variety is important in dry milling

Hard endosperm varieties have been found to yield more large grits per bushel and more profit for the miller. Recent studies in Japan and Korea funded by the U.S. Feed Grains Council have demonstrated to millers in those countries that purchasing these varieties of corn can increase profits by $0.20 to $1.00 per bushel.

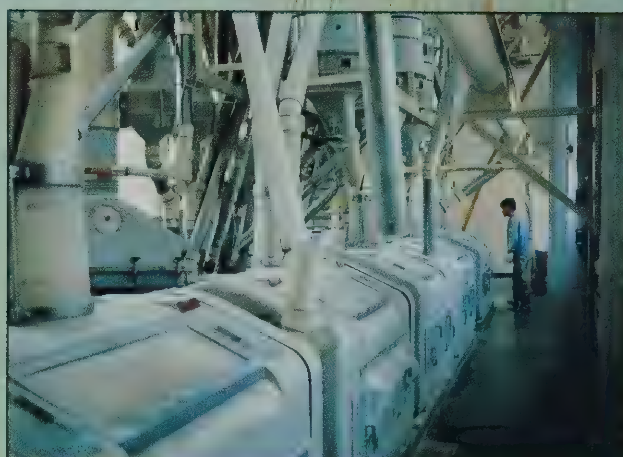
A major problem in supplying international millers with this quality of corn is that the U.S. grain merchandising system has no low-cost method of keeping such corn segregated. U.S. millers overcome this problem by paying a premium for corn either directly to farmers or through selective purchasing.

Drying conditions affect yields

Another important factor in corn quality for milling is the conditions used in drying corn. Conventional high-temperature drying, above 140°F (60°C), causes the development of stress cracks in corn, which greatly reduces the grit yield in dry milling. In wet milling, chemical and physical changes in the corn during high-temperature drying can cause a 5 to 10 percent decrease in starch yield. Currently, no accepted laboratory method is available to determine rapidly whether a corn lot has been high-temperature dried.

Researchers at the University of Illinois are trying to increase domestic and international corn utilization by improving the profitability of corn milling. Their work involves developing new products and new processes as well as determining the most important characteristics of corn needed for the two milling systems. The increased utilization of corn due to new products and more economical processes will ultimately result in more profit for Illinois farmers.

All corn is not created equal. The most appropriate corn characteristics, such as hard or soft endosperm, and the drying procedure used must be identified so that the right corn can be used in each milling process.


Dry corn milling roll stands in Korean mill.

Steven R. Eckhoff, associate professor; Marvin R. Paulsen, professor; and J. Bruce Litchfield, assistant professor, Department of Agricultural Engineering

Developing Markets for Illinois Agricultural Products

Richard A. Vogen

As long as food has been produced for organized society, a demand for agricultural products has existed. Occasionally, the demand is obvious as in the case of Jacob, who having heard that there was grain in Egypt, sent his sons there to buy some. Pharaoh did not have to market very aggressively to meet this obvious demand of Jacob and his starving sons. More often, however, competition is fierce, and demand must be developed through marketing.

Market development is a discipline used in many industries to enhance the existing demand for a product; it is especially useful for products with relatively uniform characteristics, such as agricultural commodities.

Closely related to this discipline is stimulation marketing, which creates a demand where none previously existed. In recent years, for example, demand was created for corn sweeteners and ethanol; and important markets were stimulated for these products.

Giving Buyers What They Want

Effective marketing relies on discovering the needs, wants, and preferences of actual and potential buyers of a product to serve as bases for decisions involving its design, production, pricing, method of communication with its market, and distribution. Successful marketing management, therefore, requires thorough analysis, planning, implementation, and control of marketing programs.

How Agricultural Markets Differ

The same principles of marketing hold true for agricultural products, but Illinois farmers, as producers of essentially raw materials, may face different marketing problems than those seen by many other people in business.

Lack of control. With the exception of direct marketing of some perishable and specialty products, agricultural producers seldom control marketing beyond the farm gate.

Same basic well-known products. Agriculturists are in a somewhat unusual position because many have the same basic products, and these products or their substitutes are reasonably well known to their markets. But for a number of reasons, the full potential of these markets may remain undeveloped: inefficient product utilization, lack of purchasing power, and logistical impediments. To develop these markets, individual producers need to pool their resources or find public resources.

Expanding Markets at Home

Market development is often thought of only in relation to exports. Foreign markets do offer excellent potential for further development, but domestic markets for food and agriculture can also benefit from market development. Major commodity organizations have influenced the demand for their commodities through a variety of programs: advertising, product education, product development, and various promotional activities.

The markets for Illinois's most abundant commodities — corn, soybeans, pork, beef, and dairy products — for instance, have effective market development programs. Lamb and wool, apples, peaches, nursery products, wood products, vegetable crops, and even honey, horseradish, and other products also derive benefit from market development and could potentially be expanded.

Checkoff Programs

Producer programs that check off funds at the first point of sale, such as the Illinois Corn Marketing Program, the Illinois Soybean Operating Program, the Illinois Apple and Peach Marketing Program, the Illinois Sheep and Wool Marketing Program, as well as national checkoff programs for pork, beef, and dairy, can accumulate resources for very effective market development. These programs conduct market analysis and research aimed at the development of new products or better marketing systems for commodities. Either can yield dividends when consumers' needs and wants are satisfied. These programs also seek to encourage new uses of traditional products.

State Efforts Promote Products

Statewide promotional efforts can be directed toward developing consumer loyalty for locally produced, high-quality products. The campaign by the Illinois Department of Agriculture (IDOA), which uses the Illinois Product Logo to promote state products is just one example.

Research indicates that Illinois consumers would like to purchase more Illinois products but often have found it difficult to identify a product's origin. Intended for use in the merchandising and advertising programs of individual Illinois growers, processors, and food manufacturers, the Illinois Product Logo shown here eliminates this problem by identifying this state's products. Illinois companies may also include it on package labeling. To apply for authorization to use the new logo, write or call the Illinois Department of Agriculture, Division of Marketing, State Fairgrounds, P.O. Box 19281, Springfield, Illinois 62794-9281; (217)782-6675.

Market development for Illinois processors and manufacturers of food products will increase not only opportunities for employment in those industries but also the demand for the raw materials used in manufacturing and processing. For many sectors of agriculture, strategically located processing facilities are essential to the development of a market for producers. The Illinois Farm Development Authority is instrumental in providing capital for such ventures.

An important aspect of market development is the fostering of relationships between buyers and sellers through business referrals and formal commercial activities, such as trade shows. Illinois's trade referral service and Illinois Food Expo shows, administered by IDOA, serve some of these needs. Small companies can benefit in particular from these services. For example, Eli's, a small but rapidly growing Chicago-based cheesecake company, has effectively used state programs to increase distribution into national food service and retail markets.

Developing markets abroad

The United States has organized a sophisticated network for international market development of agricultural products, mainly overseen by the Foreign Agricultural Service of the U.S. Department of Agriculture (USDA). A group of cooperators from the government and industry, including the American Soybean Association, U.S. Feed Grains Council, and Mid-America International Agri-Trade Council, has combined public and private resources to carry out worldwide programs of market development for an impressive array of U.S. food and agricultural products.

The USDA's "Targeted Export Assistance," export credit guarantees, export bonus programs, and "Food for Peace" programs have also been effective tools for trade, enhancing demand for U.S. agricultural commodities in many markets where the extra incentive is necessary to compensate for limited purchasing power and to overcome unfair trade practices by foreign governments.

Other organizations and institutions play significant supporting roles in market development for Illinois agricultural products, including the state's agricultural colleges and experiment stations, as well as the Illinois Farm Bureau, the commodity exchanges, local and municipal economic development agencies, and various support businesses, such as financial institutions and transportation companies.

Illinois is poised not only to reap the benefits of the commodity trade, but also the benefits of many of the diversified international opportunities in foods, specialty products, and agribusiness products and technology. Illinois's consistently high farm production, coupled with excellent waterway and rail transportation to major ports, has given us an advantage in the export of corn and soybeans.

Moreover, we in Illinois can add value to our products through manufacturing, and we can develop additional markets overseas. Some countries, like Japan, are becoming large markets for processed foods, such as variety meats, and for packaged meals, fruits, and vegetables. Other markets, like China, present opportunities in grain storage equipment, agricultural chemicals, and breeding animals.

In concert with the export trade and reverse investment activities of the Illinois Department of Commerce and Community Affairs, with export financing by the Illinois Export Development Authority, and with special export projects of the Illinois Export Council, IDOA assumes responsibility for international food and agricultural market development on the state level. Providing information, consulting, and marketing promotions are the primary functions of IDOA's Bureau of International Marketing, which finds Illinois products for foreign inquirers and business leads for Illinois companies.

More competitive marketing

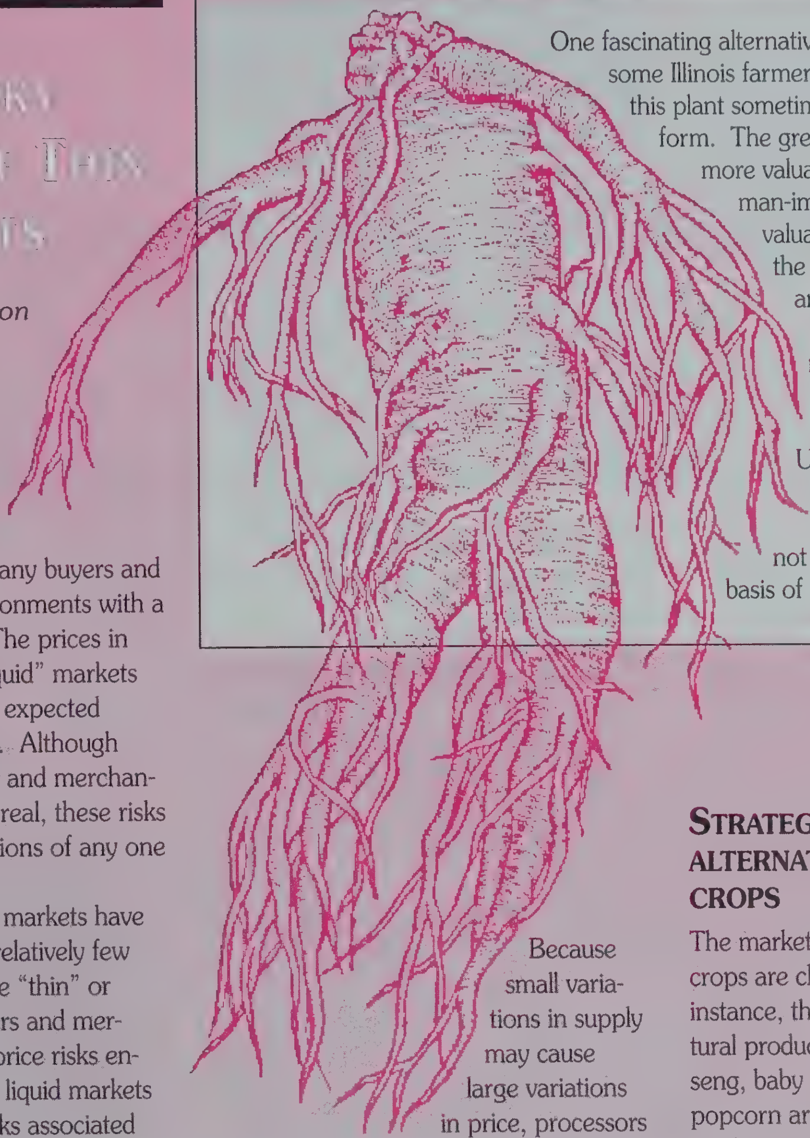
U.S. market development has become so sophisticated that competitors have adopted excellent programs of their own. The future of agricultural marketing promises to be increasingly competitive, so the scope of market development will necessarily expand and change.

A market, however, is never fully developed. One market opportunity leads to another. Creative energy drives this process of innovation and growth.

Richard A. Vogen, former superintendent, Division of Marketing, Illinois Department of Agriculture, and regional director — Eastern Europe and the Soviet Union, U.S. Feed Grains Council □

The Risky Business of Thin Markets

Sarahelen R. Thompson



One fascinating alternative crop being considered by some Illinois farmers is ginseng. The root of this plant sometimes resembles the human form. The greater the resemblance, the more valuable the root. An intact, man-image root is all the more valuable if it has been found in the wild state, especially if it is an Asiatic wild ginseng.

Old ginseng roots with many rings are also considered more valuable in the Orient; few people in the United States concern themselves with the significance of the rings, so ginseng is not purchased here on the basis of rings.

In a number of important agricultural markets, such as the markets for corn and soybeans in Illinois, many buyers and sellers do business in environments with a large volume of trading. The prices in these easily accessible, "liquid" markets closely approximate those expected under perfect competition. Although price risks to the producer and merchandiser in these markets are real, these risks are not affected by the actions of any one individual in the market.

Many other agricultural markets have low volumes of trade and relatively few buyers and sellers. In these "thin" or "illiquid" markets, producers and merchandisers face the same price risks encountered when trading in liquid markets as well as the costs and risks associated with trading in thin ones.

Why is thin-market trading more risky and expensive?

The first explanation is that market information may be scarce and marketing opportunities difficult to recognize. Obtaining information and discovering market opportunities may entail direct expenditures by the producer or merchandiser.

Another reason for the additional risks and costs is that prices in a thin market may be strongly influenced by the actions or marketings of individual traders. Prices, therefore, are affected by the quantity marketed, and the trading environment is conducive to the exercise of monopolistic power. Monopolies exist where one firm or a few firms acting together pay sellers a lower price than would be paid under competitive conditions.

Because small variations in supply may cause large variations in price, processors of thinly traded commodities often contract with producers for processing supplies. Although contracting may provide information to producers about expected price, it may also limit their marketing opportunities if few buyers other than contracting processors are available — a third reason for the additional risks and costs inherent in thin-market trading.

Finally, merchandisers in these markets may require large gross margins to justify trading in a risky environment with low volumes of trade. A gross margin is the difference between the price the merchandiser pays to suppliers and the price received by merchandisers from buyers. Large gross margins imply lower prices to producers than those received in more liquid markets. These lower prices are yet another source for the additional costs and risks found in trading in thin markets.

Strategies for marketing alternative and specialty crops

The markets for alternative and specialty crops are characteristically thin. For instance, the markets for sheep, aquacultural products, shiitake mushrooms, ginseng, baby vegetables, white corn, and popcorn are all relatively thin in Illinois. Market opportunities should be carefully researched by prospective producers to determine the profit potential of these animals and crops. Buyers must be identified in advance, and forward contracting should be investigated.

For many of these markets, producers could find themselves with far lower returns than expected if they do not thoroughly analyze the effect on price of a small increase in supply. For some producers, however, these crops may offer attractive returns if markets, once discovered, are accessible, and if prices either can be set by a forward contract or predicted with a high degree of confidence.

Sarahelen R. Thompson, assistant professor of agricultural marketing, Department of Agricultural Economics

Promoting Agricultural Commodities

Michael A. Hudson

In recent years, campaigns to promote or further the growth of agricultural commodity consumption have significantly increased. Promotion programs for cattle, hogs, corn, soybeans, and numerous specialty crops have been created with checkoff funds from commodity producers. Specific products targeted to niche markets have been promoted by groups of producers who have banded together for this purpose.

Although such interest in promotion is by no means unique to agricultural products, the expanded emphasis in recent years raises a number of questions: Why has the sudden explosion of advertising and promotion programs for agricultural products occurred? Who should bear the cost of advertising and promotion programs? Who really benefits? Should the programs be generic or product oriented?

To answer these questions, we need a perspective on the promotion of agricultural products that includes the rationale behind promotion programs, a brief examination of their history, and discussion of some ongoing related issues.

Why do we need to promote agricultural products?

When selling a product, any number of factors are important, including its form and the time and places it is available. The task of advertising and other forms of promotion is to communicate these factors to current and potential consumers.

Aims. Besides informing, promotion is used to persuade, to remind, and to reinforce. The highly successful Nutri-Facts campaign conducted by the National Live Stock and Meat Board in the mid-1980s illustrates each of these activities: it *informed* the public about the nutritional attributes of meat and meat products; it *persuaded* consumers to continue their use in spite of the negative press related to the potential health risks; it implicitly *reminded* those already consuming the product about its benefits; and it *reinforced* the satisfaction of those consuming it both before and after purchase. Effective promotion, therefore, creates or heightens consumer awareness — particularly about desirable product attributes.

Stages in the life of a product. Figure 1 depicts the five stages in the life cycle of a product in terms of the levels of its consumption. During the *developmental* stage, promoters often try to make consumers aware and solicit their input about the form of the product. Once developed, the product is *introduced* in the marketplace, where its level of consumption increases slowly as awareness gradually increases. Then with increasing availability, the product moves into the *growth* phase, in which more

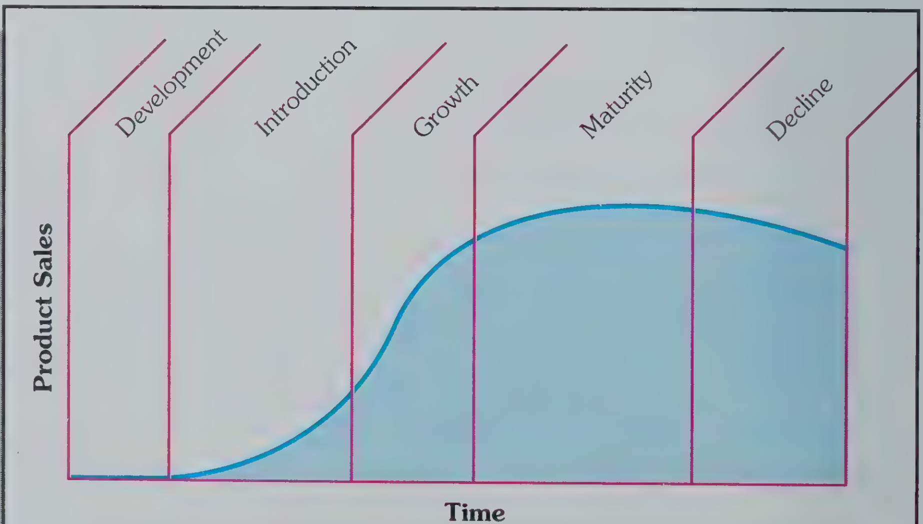


FIGURE 1. The product life cycle.

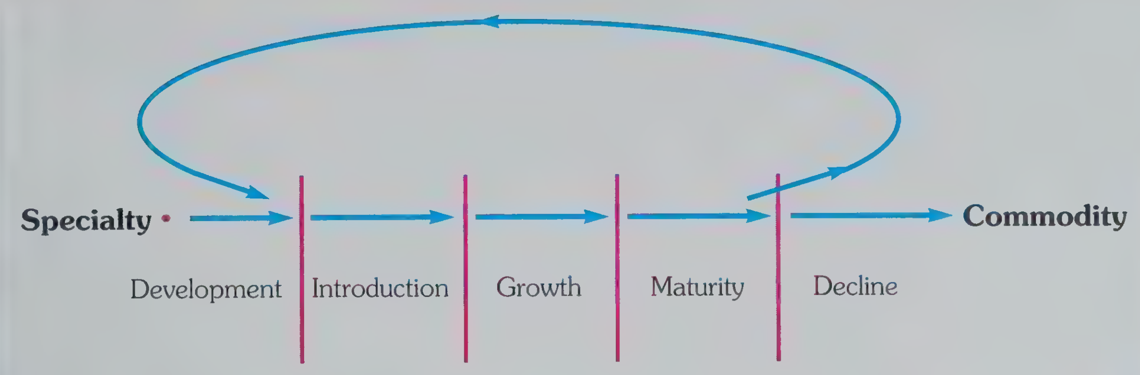
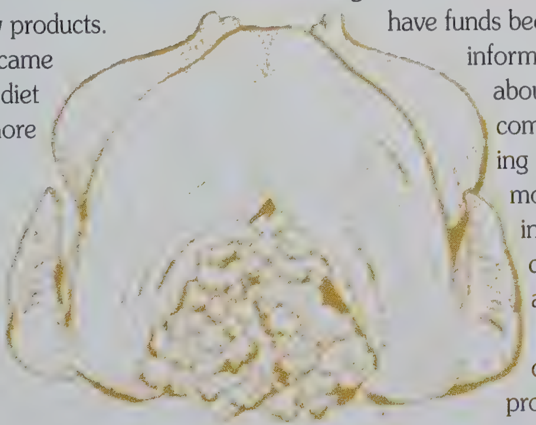


FIGURE 2. The bent-arrow effect of innovation on a product's life cycle.

consumers begin to purchase it. At some point, however, the market begins to become saturated, and the rate of growth levels off. This *mature* stage is followed by a *decline* in consumption, which is often associated with substitute products entering the marketplace.

An example of the product life cycle can be seen in the beef industry over the past four decades. In the 1950s, following World War II, beef entered the growth phase as consumers developed a taste for grain-fed beef and the product was introduced on a wide scale. During the 1960s and early 1970s, growth continued. But in the late 1970s, the market matured, and substitutes entered — such as processed poultry products. As consumers became concerned about diet and health and more interested in convenience, poultry products were substituted for beef products, moving the product into the stage of decline.



Innovation — the key to new growth. Markets for products mature, and eventually their consumption declines unless some innovation is made to launch the product into a new life cycle. A product may be a specialty product when introduced, but it becomes a commodity as it moves through its life cycle. The key to stimulating new growth is to bend backward the arrow in Figure 2 depicting the product's growth and make the commodity a specialty item again — thereby beginning a new life cycle. Familiar examples of innovations in products and the promotions associated with them are the microwavable hamburger and precooked vacuum-packaged beef roast.

HISTORICALLY, GENERIC APPROACH TAKEN

Although the maturity of markets for agricultural products is a relatively recent phenomenon, the promotion of agricultural products has a long and rich history. Much of it records attempts by commodity groups to increase the demand for a generic commodity. Only recently have funds been focused more on informing consumers about the benefits of commodities, developing new forms of commodities, and promoting specific brands of commodities, such as Angus beef.

Legislated producer promotion programs were first initiated in the mid-1930s when the Florida legislature passed a number of citrus regulations aimed at helping the depressed Florida citrus industry. By 1940, five states had passed similar checkoff programs: Idaho adopted one for vegetables; Washington and Michigan, one for apples; Maine, one for potatoes; and Iowa, one for milk. The number and scale of such programs have grown greatly since 1940: 312 legislated programs covering 80 different farm commodities are currently in effect.

One of the most important changes in recent years was the consolidation of state promotional programs for dairy, beef, and pork. These programs were nationalized to facilitate better coordination across states and to ensure equity of contributions from all commodity producers. To gain political support, local and regional groups have been assured a significant share of promotion and research efforts.

ISSUES INFLUENCE FUTURE OF PROMOTION CAMPAIGNS

The success of commodity promotion programs is largely dependent upon the level of participation in them, the nature and scope of the promotions, and their impacts on consumers. Although there is no doubt that these programs have been important for numerous commodities, there is by no means unanimity of agreement about the need for them.

Tapping into Demand with Effective Advertising

Noreen N. Frye

Consumers choose among a variety of products every time they make a purchase, and many of those choices are influenced by advertising and promotion. The message carried by advertising is intended to create awareness of a product. But a creative, well-thought-out advertising campaign can do much more; it can create an image for a product and even change one a product already has.

The pork industry's advertising campaign is an example of how advertising can have a dramatic impact on sales and consumer attitudes. The National Pork Producers Council has a history of creative advertising, building campaigns around such catchy messages as "America, you're leaning on Pork" and "Pork, What A Good Idea." In the early 1980s, however, pork was losing out to other kinds of meat at the meat counter.

The Council hired an agency to research consumer attitudes toward pork and develop a communication and marketing program to attract consumers to it. The agency found that many consumers avoided pork because they thought consuming it was less healthy than consuming other meats.

To counter that image, the agency created the message: "Pork, The Other White Meat." They developed advertisements showing pork prepared in versatile, new, healthy ways.

The new message and campaign in test markets changed consumer attitudes about pork in a matter of months. As the other white meat, pork became light, lean, and nutritious — the qualities consumers associate with fish and chicken. Attractive, tempting pork dishes advertised on television showed the versatility of pork and stimulated sales at meat counters.

Rozmarin and Associates, an independent research firm in Omaha, Nebraska, measured consumer reactions to the new campaign against a study conducted before the campaign got under way. It reported that consumer association of pork as a white meat increased 163 percent after only 6 months' exposure to the new campaign. In some test markets, consumer recall of the primary message of the campaign was as high as 72 percent.

Effective advertising depends not only on finding the right message and developing a campaign, but also on sustaining the effort. The pork industry attracted consumers with a message in 1987 and 1988. Now, it intends to reinforce that message through television and radio advertisements in major metropolitan areas where pork is not selling well and in national consumer magazines.

State organizations, under the guidance of promotion committees, will target major cities for advertising. Chicago and Rockford are target cities in Illinois. The Illinois campaign is diverse, including television advertising tied to sport and other consumer special events, radio and newspaper advertisements, billboards, and retail promotions.

The market for pork has increased since the new campaign started. That increase means the demand was always there. Advertising was a tool for tapping into that demand.

Noreen N. Frye, director of product marketing, Illinois Pork Producers, Springfield, Illinois

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Several issues coloring the debate in recent years are likely to continue having an impact on the promotion of Illinois's agricultural commodities and products.

Support base. Of the four primary approaches to funding promotion programs — public, producer, voluntary, and mandatory funding, the voluntary approach has been the historical backbone of these programs. In recent years, however, voluntary funding has been replaced by a legislated mandatory approach. Despite the mandatory nature of these programs, some producers debate their true benefits, sometimes resulting in an unwillingness to provide support. This unresolved issue may ultimately lead to some restructuring of promotion programs and distribution of funds.

Geography and money. The geographic dispersion of commodity producers, coupled with the mandatory "checkoff" nature of many promotion programs, raises a number of questions related to the dispersion of funds. Of particular concern is whether commodities should be promoted regionally or nationally. Also controversial is the allocation of funds for research, often conducted at land-grant universities. The potential benefits of allocated funds and where the research will be conducted generate much discussion. Maintaining an equitable balance in the resolution of this complicated issue may require much effort.

Generic versus product focus. Many promotions funded by these programs are targeted toward generic themes, like "Beef Is Good Food" and "Pork, The Other White Meat." Some experts would argue that product promotions are more effective, such as the "America's Cut" campaign.

At the heart of the debate about commodity

The National Pork Producers Council adopted this official porkmark and slogan to speak with a unified and clear voice to its various publics.

pork®

The Other White Meat®

promotion programs is the question of who benefits. Generic advertising appears to benefit more producers, but when ineffective, it threatens the survival of commodity programs. In terms of benefits received, product-specific promotions may be more effective but are likely to exclude some of the producers who are footing the bill.

Evaluating the impact of promotion campaigns. The impacts of generic and product-specific promotion programs are difficult to assess. The academic research community has an important role to play here in developing appropriate models for measuring the returns to these expenditures.

This task is extremely difficult, however, in mature markets, where some expenditures may be simply staving off further declines and not resulting in significant increases in consumption. Analysts need to consider the success of promotions based on their ability to inform, persuade, remind, and reinforce. Measuring only their ability to persuade, shown by increased purchases, is misleading and will likely understate their true success.

Program longevity. Although a number of promotion programs have existed for many years, the future of these programs is uncertain. The case could be made that such programs are needed only for a short period of time — when markets mature — and that they are not needed in the long run. However, as long as the production of agricultural commodities remains in the hands of geographically dispersed and independent producers, such programs are likely to be needed for maintaining and expanding markets.

Promotion programs for agricultural commodities have a long history. Although viewpoints vary about their success and impact, these programs provide an important means of creating consumer awareness, which would otherwise not exist for many commodities. The structure and impact of such programs are likely to be a source of continuing debate and will no doubt be significantly influenced by the success or failure of current programs. Producers and economists have important roles in these discussions: ensuring equity of programs and measuring their impacts.

Promotion programs will quite likely continue expanding in the next decade although their full scope will depend on the evolution of the food and agribusiness sector. The tremendous potential for producers and groups of producers to develop specific market niches suggests that these programs will continue to play an important role. No doubt, in the near future some innovative moves will be made in the design and delivery of promotions and the evaluation of their impacts.

Michael A. Hudson, associate professor of agribusiness management and marketing, Department of Agricultural Economics

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For more information about the promotion of agricultural commodities and products, write or call the following organizations:

- National Live Stock and Meat Board
  444 North Michigan Avenue
  Chicago, Illinois 60611
  (312)467-5520;
- National Cattlemen's Association
  5420 South Quebec Street
  P.O. Box 3469
  Englewood, Colorado 80155
  (303)694-0305;
- National Pork Producers Association
  P.O. Box 10383
  Des Moines, Iowa 50306
  (515)223-2600;
- National Corn Growers Association
  1000 Executive Parkway
  Suite 105
  St. Louis, Missouri 63141
  (314)275-9915;

or

- American Soybean Association
  P.O. Box 27300
  777 Craig Road
  St. Louis, Missouri 63141
  (314)432-1600.

Also available is a helpful series of six pamphlets: *Generic Agricultural Commodity Advertising and Promotion,* prepared by the Northeast Regional Committee on Commodity Promotion Programs (A.E. Ext. 88-3).

A complimentary set of pamphlets can be obtained by writing or calling:

Doris Shoemaker
Department of Agricultural Economics
52 Warren Hall
Cornell University
Ithaca, New York 14853
(607)255-2102.

Trends for Marketing Fresh Meat Respond to Consumer Concerns

Barbara P. Klein

Consumers' perceptions about the role of meat and meat products in their diet are changing, and so are the ways these foods are marketed.

Concerns reflect health recommendations and social and economic trends

Noting consumers' traditional liking for meat and meat products, surveys point to consumers' health and weight concerns, desire for "fresh" and "natural" foods, and awareness of animal production and processing practices. Recommendations from health agencies to limit cholesterol and fat intake from animal products, to reduce salt intake, and to avoid weight gain, have resulted in an unprecedented concern about the nutrient content of food, specifically with respect to meat.

Strategies for marketing fresh meat have taken advantage of the health consciousness of the consumer by providing nutrition information at the point of sale and by promoting leaner cuts of meat and low-fat recipes. "Light" or "low-fat" meat products can be prepared with greater control of the amount and type of fat to help consumers achieve their health and nutritional goals.

Leaner cuts. The leanness of retail cuts of beef and pork has improved considerably in the past 20 years. The optimum fat content of beef recommended for consumer acceptability ranges between 3 and 7.3 percent, corresponding to U.S. Department of Agriculture (USDA) grades from "Good" to "Choice," according to the 1986 National Consumer Retail Beef Study.

Marketing meat on the basis of USDA grades, however, is not an effective strategy because consumers are confused about the meaning of these grades. Surveys show that consumers look for lean meat but erroneously associate the "Prime" grade, which is highest in fat, with leanness.

Studies conducted at the University of Illinois on consumers' perceptions of meat quality suggest that tenderness, juiciness, and other characteristics that they thought important may be inconsistent with very lean meat. This contradiction must be considered in developing and promoting beef and pork that are lower in fat.

Closer trimming. Another approach to decreasing the fat content of cooked meats is marketing more closely trimmed meat. Overall fat thickness on all cuts of meat available in retail stores is less than 1/8 inch according to surveys conducted by the USDA and beef industry organizations. This amount of fat represents a gradual decrease from the industry standard of 1/2 inch since the early 1980s.

Research in the Department of Animal Sciences and the Division of Foods and Nutrition suggests that the cooked lean portion of meat has the same amount of fat whether it is trimmed before or after cooking, although trimming the fat from meat before cooking reduces the total amount of fat available for consumption. In fact, the small amount of fat trim indicates that the meat available in retail outlets is considerably lower in fat than USDA food-composition data suggest. Elimination of visible fat trim, then, is an important marketing strategy.

Lean (Good or Select) meat (above) and highly marbled (Prime) meat (below)

Easier preparation. In addition to nutritional concerns, social and economic trends indicate that consumers are looking for ready-to-eat and quick-to-prepare meat products. Developing new products, particularly precooked meats, may offer the greatest opportunity for meeting consumer demands. Positioning prepared fresh meat products either with refrigerated foods or in an in-store delicatessen brings these products to the attention of the time-conscious consumer. Studies are under way at the University of Illinois to confirm the safety and eating quality of precooked beef and pork.

Retaining foodservice markets

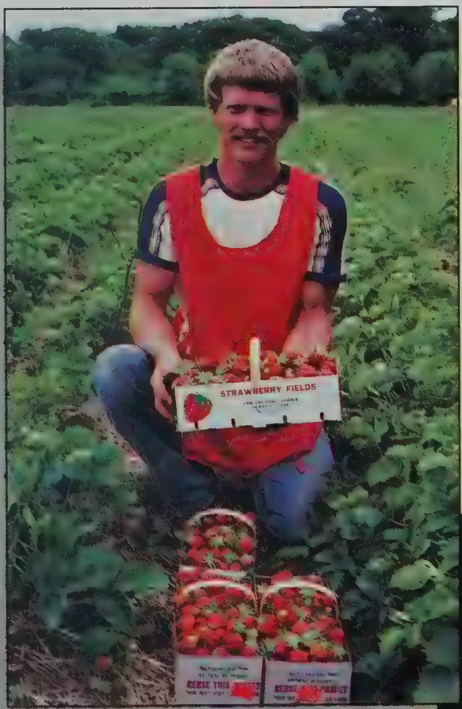
Foodservice establishments, ranging from the fast-food outlet to the "white tablecloth" restaurant, are judged by the quality of their meat products. Restaurant offerings are more diverse and cater to the "new" consumer who has larger amounts of disposable income and is more adventurous in food selection. Fresh meats other than beef and pork — such as lamb, veal, and game — are gaining new audiences. But beef and pork producers have countered by providing innovative foodservice-oriented recipes that capture the imagination of affluent restaurant clients.

Marketing strategies for fresh meats, therefore, must include providing information about food preparation to both home food preparers and foodservice operators as well as educating consumers about meat's unique contributions to the diet and supplying high-quality processed and fresh meats that are lower in fat.

Barbara P. Klein, professor of foods and nutritional sciences, School of Human Resources and Family Studies

Marketing Horticultural Products

J.W. Courter and David J. Williams



Pick-your-own strawberry operation near Gilman, Illinois (above).

Horticultural crops are in an ironical situation in Illinois. It is ironic that although many of our horticultural industries rank high in regional and national arenas, their contribution to Illinois's agricultural economy is small by comparison. Illinois farmers grow over fifty vegetable and fruit crops. They lead the nation in the production of horseradish and pumpkin for canning and are significant producers of sweet corn and green peas for processing. Other important crops for Illinois include apples, asparagus, greens, lima beans, melons, snap beans, strawberries, and tomatoes.

Also ironic is the fact that even though Illinois is a major producer of horticultural crops, according to a study conducted in 1983, it grows only about 5 percent of the fruits and nuts, 11 percent of the vegetables, and 3 percent of the potatoes consumed in the state. It imports the balance from other states and many foreign countries.

At the same time, Illinois exports fresh vegetables, processed products, apples,

Each year record-breaking crowds attend the Illinois Fruit, Vegetable, and Irrigation Convention and Trade Show (right).

and nursery crops. For instance, it is a major exporter and importer of nursery and florist products. Woody landscape plants are shipped from and to both coasts and into Canada. Flowers are received daily from Israel, Columbia, Holland, and other foreign countries.

Specialty crops

Horticultural crops are considered specialty crops, not alternative crops, because there is no practical way to convert a significant number of acres of grain or soybean production to horticultural crops. Farmers who want to grow a horticultural specialty crop should consider the following factors carefully.

Intensive culture. Many horticultural crops are intensively cultivated. A large volume and potentially high gross returns are possible from small land areas. Special skills, machinery, and irrigation are required. Gross returns can be from $1,000 to $2,000 per acre or more for many vegetables, from $3,000 to $5,000 per acre for fruit, and up to $12,000 per acre for nursery production. Full-season protected cropping in a greenhouse can gross from $15 to $20 per square foot of growing space. But overhead costs, variable production costs, and the level of risk are high.

High management. Specialty crops require a high level of management. There is no substitute for highly knowledgeable and skillful managers in growing and marketing horticultural crops. Farms may grow one or two food crops or as many as 30 or more. Commercial nurseries grow as many as 250 crops. Diversification spreads management time and often increases risk.

Labor intensive. Many horticultural enterprises demand large amounts of labor for care, harvest, and market preparation. Nevertheless, one task that always tests a manager's skills is keeping this farm labor fully employed in growing a variety of crops throughout the season.

No surpluses. Virtually all horticultural crops are perishable or highly perishable. Surpluses take care of themselves, so no programs are needed to take excess production off the market. In fact, very few crops do not tend to be overproduced when weather is favorable or high demand and high prices create an incentive to produce more of the crop. Oversupply has a dramatic effect on fresh-market price. A rule of thumb is that a 2 percent oversupply will drop prices 10 percent and a 10 percent oversupply will drop them 50 percent.

Restrictions on location. Horticultural crops often have specific climatic or soil requirements that limit their production to favorable sites. Acid soils for blueberries and good air and water drainage for fruit and nursery crops are good examples. Close proximity to markets or processing plants are obviously important considerations too. Retail nurseries and garden centers thrive in urban and suburban locations that are usually very expensive real estate.

Consumer-driven demand. Marketers of horticultural products are highly sensitive to the demands of consumers, who ultimately determine what is grown and how it is prepared, processed, packaged, and marketed. The Illinois nursery industry for the past several years, however, has been in the enviable position of not being able to meet consumer demand, particularly for large landscape plants.

Changing markets. Shifts in the number, demographics, and preferences of consumers all influence the demand for horticultural products. Today, for example, consumers' concern for health and nutrition has increased consumption of fresh fruits and vegetables, especially salad vegetables, broccoli, and cauliflower.

The demand for landscape plant materials is also changing with an increased demand for herbaceous perennials, such as hostas and daylilies, and native plant materials, such as wildflowers and prairie grasses. Even the highway department and other public consumers are changing their planting specifications for right-of-way plantings from high-maintenance grasses and exotic ornamental trees and shrubs to low-maintenance prairie grasses and native trees and shrubs.

Market niche. Relatively few ready markets exist for farmers who are first starting out to grow a horticultural crop. In general, growers seek a special niche in the market by opting for an early harvest, freshness, better quality, an improved cultivar, a unique or improved package or process, or some other competitive edge.

Market diversity

Horticultural producers have a wide range of potential markets, depending on the location of their farm, size of operation, available transportation, and marketing skills. Individual farms may sell their products in more than one market.

A fresh market survey of the Illinois Vegetable Growers Association in 1987 found that over 70 percent sold vegetables directly to consumers and that more than 60 percent sold them wholesale to terminal markets other than those in St. Louis and Chicago. A majority thought their marketing strategies could be improved and that cooperative packing would improve sales and increase acreage under production.

Terminal produce markets. Growers have consigned fresh produce to wholesale firms at terminal produce markets for many years. The South Water Market is a major wholesale fruit and vegetable market in Chicago. Buyers who depend on terminal markets include some supermarkets, grocery stores, ethnic specialty stores, restaurants, hotels, institutions, and peddlers. Terminal wholesale markets are located in most major cities. Brokers at the South Water Market also specialize in carload lots of produce that are redistributed in the upper Midwest.

The wholesale houses for floricultural crops were concentrated in the 1300 block of Randolph Street in Chicago. These markets are now dispersed throughout the six-county metropolitan area of northeastern Illinois to provide better service for both the wholesale growers and the retail florists shops. The growers in southern Illinois market some of their products at the Wall Street Market in St. Louis, where six floricultural wholesale houses are located. No wholesale markets of this type exist for the distribution of woody landscape plants.

Food processors. The acreage of vegetables contracted in Illinois with food-processing companies has been declining

for many years. This trend may have reversed with the 1989 season. About 75 percent of the estimated 110,000 acres of vegetables are grown for food-processing companies. These companies contract for specified acreage and may provide scouting services and harvesting aid. Depending on the crop, they may also specify cultivars, pesticide treatment, and planting dates.

Among the firms contracting acreage in Illinois are Stokely USA, Inc.; Del Monte Corporation; Green Giant Company; Libby, McNeill, and Libby; Razorback Farms, Inc.; Hartung Brothers, Inc.; Red Gold, Inc.; Larson Company; and Green Bay Foods.

Chain store warehouses. Large supermarket chains purchase directly from producers who deliver to their warehouses. Dominick's Finer Foods, Inc. and Jewel Food Stores are two major food chains that serve Illinois and the metropolitan Chicago area. High quality, uniformity, proper precooling and packaging, and consistent supply are prerequisites for selling to these buyers.

In 1911, Herman B. Dorner, a professor of horticulture at the University of Illinois, served as the first secretary of Florists' Transworld Delivery (FTD) and was instrumental in the development of this unique marketing system.

Chain stores are major outlets for landscape plants. Many of the large chains, such as Sears, K mart, Frank's, and Walmart, have nursery or garden departments that sell a variety of plants and gardening supplies. Nationally, these four firms account for more than 1,400 million dollars in retail lawn and garden sales. Producers must consistently be able to provide prompt deliveries to many different locations in order to gain access to these markets. Many growers do not have the distribution capacity to service them.

Local stores and supermarkets. The policy of buying local produce varies widely and often depends upon the discretion of the local store manager. Local farmers must find their market niche to develop these opportunities. Produce managers, for instance, have often found good sales for home-grown, freshly picked strawberries and sweet corn delivered daily to local stores and supermarkets.

Restaurants and fast food stores. Farmers' ability to serve this market depends on their developing personalized service, making delivery on time, and providing the quality or special crop needed.

Farmer cooperatives. Successful in many areas, grower-owned cooperatives bring together small growers to enable the co-op to pack and ship larger quantities to wholesale markets. Several small co-ops market a limited number of crops, mainly vegetables, in Illinois. This type of marketing is not used for selling landscape plants in Illinois; however, small growers have banded together into informal cooperatives to buy larger quantities of supplies and plant materials so that they can benefit from quantity discounts.

Telemarketing. Unique to the marketing of floricultural products is telemarketing. A national network of retail flower shops is linked together by a telephone system that allows a consumer to order fresh flowers in a local flower shop and have them delivered the same day or within 24 hours almost anywhere in the United States.

Farmer-to-consumer markets. Community farmers' markets, roadside stands, greenhouses, garden centers, and pick-your-own farms sell directly to consumers who live nearby. These direct markets provide an opportunity for small farms, an entry into local markets for new producers, and alternative markets for large diversified farms. Each year the Illinois Department of Agriculture publishes the "Directory of Illinois Fresh Fruit and Vegetable Markets."

Rewholesalers. "Rewholesaling" is a "new" term now used to describe the traditional activities of nursery plant brokers. These marketers buy plant material from a variety of wholesale sources, usually in large quantities to take advantage of discounts and then to resell these products to landscape contractors, garden centers, and other retail outlets. Rewholesalers in Illinois include proprietorships and large corporate nurseries, such as the Weyerhaeuser Nursery Products Division, the largest U.S. rewholesaler.

Mail order nurseries. This type of nursery delivers nursery plants to its customers by the U.S. Postal Service or United Parcel Service. These companies advertise their products through catalogs and literature sent directly to their customers. A number of mail order nurseries operate, with Illinois as their home base.

Other markets. Growers in producing regions may sell directly to nearby packers or grower-shippers, who in turn ship to distant markets. Growers of herbs and other specialty items publish catalogs and advertise to mail order clientele. Some growers are able to develop market outlets with businesses, schools, hospitals, and other institutions. These highly specialized market opportunities are limited only by the imagination and ingenuity of the grower. Illinois does not have large produce auction terminals that provide a cash market in some other states.

Consumer Preferences

A recent study by the American Florists Marketing Counsel on consumer buying trends indicates that less than half of all flowers are bought at florists' shops (see accompanying pie chart). Regular purchases at supermarkets have grown at the expense of consumer loyalty to local florists shops, but a significant group of

Where consumers buy flowers

Adapted from a study by the American Florists Marketing Counsel, 1989.

consumers buys regularly at both outlets. This group represents an opportunity for proactive florists who aggressively pursue clients.

Meet the Buyer

Identifying and developing suitable markets are factors that limit horticultural production in Illinois. Market forces will continue to bring many changes, and we are optimistic that Illinois's resources of water, soils, and central location in respect to a large percentage of the U.S. population will provide increased opportunities.

The Illinois Fruit, Vegetable, and Irrigation Convention is striving to improve marketing knowledge and communication. This year, for example, the convention sponsored and promoted a "Meet the Buyer" program, through which farmers learned about potential crops from buyers with a number of companies.

National nursery crops survey

The University of Illinois Department of Horticulture is participating in a national survey of the nursery industry. Eighteen of the largest nursery-crop-producing states are compiling basic production and marketing data about their share of the $7-billion wholesale nursery industry.

Improved collection of statistical information about the kinds of crops planted, acreages, and the value and use of natural resources by Illinois horticultural industries is needed. If the Illinois Agricultural Statistics Service could provide this information, it would be an invaluable guide to future research programs of the Illinois Agricultural Experiment Station.

J.W. Courter, professor of horticulture and Extension specialist, small fruit and vegetable crops, Dixon Springs Agricultural Center, Simpson, Illinois, and David J. Williams, professor, Department of Horticulture

Farm Trade Areas: A New Concept in Direct Marketing

J.W. Courter

The principal market for 1,800 acres of small fruits in Illinois are consumers who live in nearby communities. These customers drive to pick-your-own (PYO) farms to get a quantity of berries, to select the best berries, and to save money. They choose one farm over another for the ease of picking, the price, and loyalty based on previous experience.

Among the most popular crops sold by Illinois PYO farms are strawberries, blueberries, raspberries, blackberries, apples, beans, peas, tomatoes, and greens.

Trade Areas for Agricultural Businesses

The concept of retail trade areas has been researched and defined for food stores and shopping centers for many years, but the idea has not been generally applied to agricultural businesses or farms.

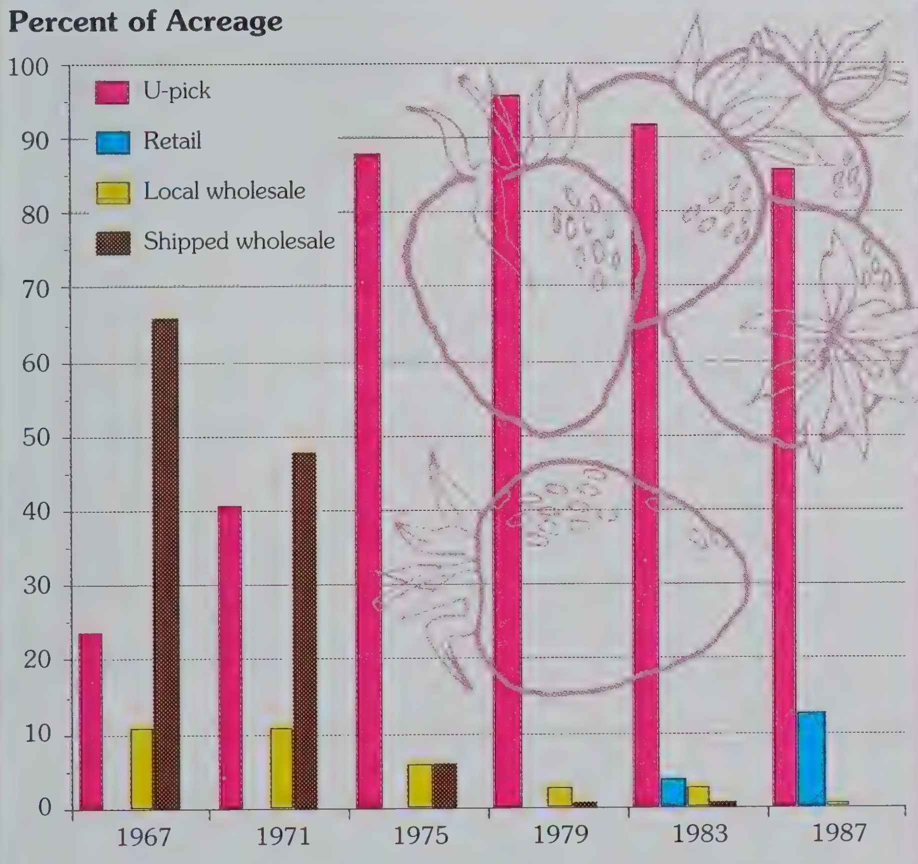
The trade area of each PYO farm is not a perfect circle surrounding the farm; it is where the farm's customers live. This area can be described geographically and delineated by access roads; mountains, rivers, and other natural barriers; and the location of competition. Poor and winding roads, limited travel routes, and long distances from populations deter consumers from picking their own. Farms with large trade areas are vulnerable to competition.

The primary trade area for an Illinois strawberry farm, for example, is the geographical area where 75 percent of all its customers live. They are the basis for repeat business. For strawberry customers, the average trade area is a 20-mile radius around a farm that sells strawberries.

In a statewide survey conducted in 1985, I have found that 71 percent of households bought fresh strawberries and that 19 percent picked their own. A higher percentage of households in rural areas picked strawberries than households in heavily populated metropolitan areas. I have also found that an acre of strawberries can be marketed to a rural population of 2,500 within 20 miles of the farm.

The ratio changes on operations near big cities: one acre of PYO strawberries for a population of 10,000. The difference in these ratios may be due to the fact that many city residents either do not know about the opportunity to pick their own or lack transportation. Of those who did not pick strawberries in the 1985 survey, 53 percent were not aware of the PYO opportunity. Marketing trends for strawberries in Illinois are shown in the accompanying figure.

Each farm, however, is unique, and crops other than strawberries have different yield and consumption patterns.



Strawberry marketing trends in Illinois

Projections Guide Marketing Decisions

Defining the trade area helps provide preliminary estimates for establishing a marketing plan. Farmers use trade-area projections to expand their present acreage, discover new opportunities, develop their advertising plans, and pinpoint overly competitive locations. If, for instance, 4 acres of strawberries require 1,500 or more customer sales, participation by 20 percent or more of all households living in a primary trade area of 10,000 people is required for a successful PYO venture.

Limited populations, therefore, will not support a large PYO acreage. Farms in these areas should only consider a PYO business as an opportunity to employ family labor and to supplement other income.

J.W. Courter, professor of horticulture and Extension specialist, small fruit and vegetable crops, Dixon Springs Agricultural Center, Simpson, Illinois

Illinois's forest resources — marketable assets.

Opportunities for Marketing Forest Products

Gene E. Campbell and Gary L. Rolfe

Typically what comes to mind when we think of forest products is lumber, Christmas trees, or firewood. Forest products, however, encompass much more. From the morning newspaper to the home we come back to in the evening, the average person uses or comes in contact with hundreds of products from the forest each day. These demands on our forest resources for fiber, food, and chemicals are expected to continue increasing as our population grows and as new forest products are developed.

In Illinois, 4.3 million acres or 12 out of every 100 acres are forested. Ninety-four percent of this forestland is classified as commercial timberland; and 90 percent of this timberland is owned by farmers and other private individuals.

With nearly 30 forest cover types, these private nonindustrial forests are very diverse, the most common type of forest cover in Illinois being a combination of oak and hickory. In 1985, 98 percent of the 4.8 billion cubic feet of timber growing stock was hardwoods.

Timber products

Timber removals from growing stock in Illinois totaled 68.6 million cubic feet in 1984. This timber stumpage was cut into logs for veneer or lumber, pulpwood, fuelwood, posts, or other products. These primary forest products are used by the secondary manufacturing industries in the United States to produce the vast array of consumer goods in the marketplace today.

Some products are used in the manufacturing process itself: pallets, jigs, and packaging. Lumber is the product used in greatest amounts, followed by particleboard, plywood, bolts (rough timber), veneer, medium-density fiberboard, insulation board, and hardboard.

Hardwoods

The hardwood export market also is significant and increasing in importance. For example, between 1970 and 1986, U.S. exports increased by 102 percent for hardwood logs, 329 percent for lumber, 442 percent for veneer, and 611 percent for plywood. Much of this increase has been for white and red oak products in the European market and in the expanding Asian market.

In 1986, 688 million board feet of hardwood logs and lumber, and over a billion square feet of hardwood veneer and plywood were exported. Major importing countries were Canada and West Germany, with increasing exports to Japan and Taiwan. Significant amounts of hardwood are also exported to Belgium, the Netherlands, France, Switzerland, Great Britain, Denmark, Italy, and Mexico.

Opportunities for expansion

For the last 10 years, Illinois has ranked in the top five states in the use of forest products, but its manufacturing industries import nearly 70 percent of this wood from other parts of the country. Much of the imported wood is hardwood. An excellent opportunity, therefore, exists for substantial expansion of forest product markets available to owners of Illinois forestland. This expansion, which would

benefit both the primary and secondary wood-using industries of the state, could be achieved in a number of ways.

Increasing the supply of timber. One method of creating more forest product markets is to increase the supply of timber. An immediate increase could be obtained by simply increasing the timber harvest. It is estimated that only one-third of annual forest growth is harvested and processed by the primary industries in Illinois. Short- and long-run supply could be enhanced by increasing seedling production, selecting genetically superior seedlings, converting marginal agricultural land to forestland, improving timber management and harvesting practices, and increasing wood utilization.

Increasing primary manufacturing. This increase could expand markets for forest products by making more of Illinois forest resources available for secondary manufacturing. In particular, the capacity of dry kilns must be increased, and the utilization of sawmill wood must be improved. These steps would significantly increase the production of high-grade lumber from Illinois's forests.

Compared to surrounding states, Illinois has relatively high workers' compensation, unemployment insurance, and utility rates as well as high truck license fees. Making these more equitable would encourage more forest industries to settle in Illinois.

Increasing marketing efforts. Marketing efforts must be increased. Forest products harvested in Illinois are often manufactured and marketed in such a way that landowners, loggers, sawmills, and other wood-processing firms receive less than full value for their products.

Steps to improve marketing include owners' obtaining multiple bids when selling timber and their planning timber sales to coincide with favorable market periods. Greater knowledge of proper wood utilization and marketing techniques also is needed, as are better knowledge of and access to sources of investment capital. In addition, markets for low-quality and fast-growing trees must be improved by developing new products and promoting on-farm energy use of forest biomass and other uses of forest products.

Knowing about nonwood forest products. Wood products are not the only commodities produced in the forest. By producing forest-related nontimber products, such as ginseng and shiitake mushrooms, and expanding recreational opportunities, forest product markets can be diversified and expanded further.

With current technology, we can significantly improve marketing opportunities for Illinois forest products. Through proper market development, Illinois will benefit more fully from utilization of its forest resources. Advances in biotechnology, improved utilization, and product development will increase these opportunities and benefits.

Gene E. Campbell, assistant professor, and Gary L. Rolfe, professor and head, Department of Forestry

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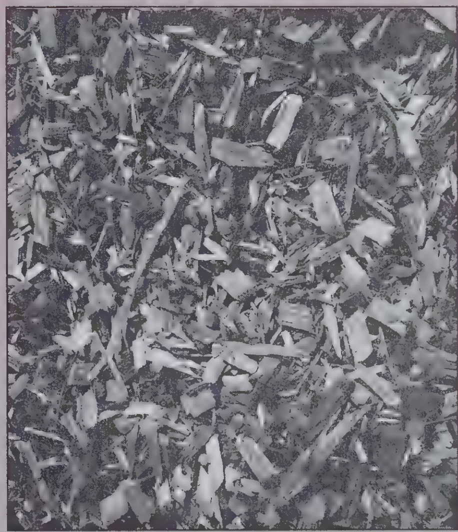
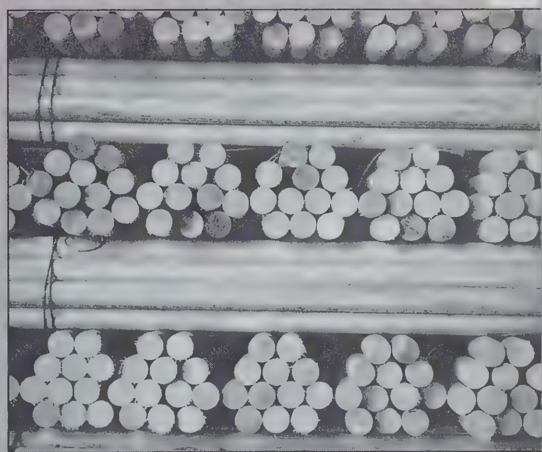


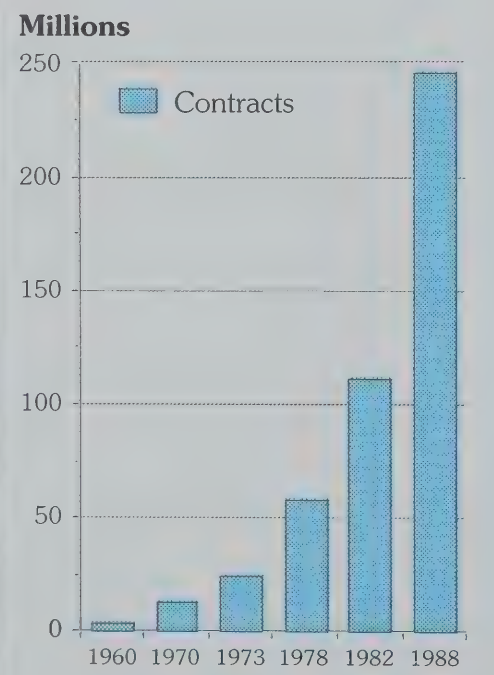


Lumber, wood chips, and dowels are only three of the many forms that forest products take.

Commodity Futures and Options Markets: Tools of the Trade

Philip Garcia, Raymond M. Leuthold, and Robert J. Hauser

Only about 2 percent of futures contracts are ever held to maturity and liquidated by delivery. Why then have the futures markets been such an integral part of our economy and agricultural marketing system? Why, for example, have the futures markets in Chicago been in existence for more than 125 years? These markets not only exist but also continue expanding because they help our economy and agricultural marketing system to function more effectively.



Trading volume in U.S. futures markets for selected years

Traditionally, futures contracts existed for only storable agricultural commodities and metals, but in the mid-1960s, the markets expanded to include nonstorable livestock commodities. This expansion was followed by the introduction of contracts for foreign currencies; treasury bills, bonds, and other financial interest-rate instruments; petroleum products; and stock indexes, among others. Since 1984, we have seen the introduction of options on many of these futures contracts. Currently, futures and options markets in the United States are global in nature, and futures exchanges are exploring methods to extend trading hours to 24 hours a day around the world.

The accompanying chart demonstrates the tremendous growth in futures trading over the last three decades. The total face value of all futures and options contracts now traded amounts to several trillion dollars annually.

Mechanics of trading

About three-quarters of U.S. futures contracts are traded in Chicago, either at the Chicago Board of Trade or at the Chicago Mercantile Exchange. The exchanges provide the facilities and rules for organized trading of contracts.

The contracts themselves are an agreement between a buyer and seller to exchange a well-defined commodity or instrument at a fixed price in the future. They are easily liquidated though offsetting transactions. Almost every aspect of a futures contract — including its size, the delivery site, the quality of the commodity, and the month of maturity — is highly standardized.

At the time a contract is created, no title changes hands, and only minimal amounts of money are posted by both sides to guarantee performance. Although only exchange members can trade futures contracts on the trading floors, trading is open to and done by the public through brokerage houses. Traders might be either speculators absorbing price risks or hedgers using the markets to forward price and manage risks.

Trading of futures and option contracts also is regulated by the federal government. Federal regulation is carried out by the Commodity Futures Trading Commission (CFTC), a five-person administrative body appointed by the President. Its primary purposes are to ensure proper execution of customer orders; to prevent or curb unlawful manipulation, price distortion, fraud, cheating, fictitious trades, or misuse of customer funds; and to assure the general solvency of the system. Together, the exchanges and the CFTC keep futures trading competitive, and relatively free of price fixing and collusion.

Functions of the futures markets

An important institution for many U.S. commodities, futures markets are extensions of the cash markets. Having evolved out of existing market forces, they make cash markets work better. They help forward price commodities and instruments

Buyers and sellers respond to changing market conditions.

— a speculative, unavoidable process in marketing. By establishing a price for the commodities or instruments to be sold in the future, the markets augment the degree of certainty in business decisions. Markets also shift risk and disseminate information — critical economic functions that facilitate the production and marketing of many commodities. In addition, they can facilitate the securing of capital.

Forward pricing. One of the most important functions performed by the futures market is the pricing of agricultural commodities. Prices are discovered by the market activities of many buyers and sellers through a public exchange of bids and offers. They reflect the market's information about actual and expected supply-and-demand conditions. In effect, they provide the market's expectations about subsequent cash prices.

For grains, current prices are closely linked to future prices through the price of storage. For nonstorable commodities, futures markets directly provide their view of future supply-and-demand conditions.

In addition, futures markets have fostered the development of numerous sources of information about actual and expected supply and demand — information that can be extremely useful to producers and other market participants in coordinating their activities.

Determining the size of inventories. Effective price discovery is particularly important for the activities of agricultural markets and their users. For grains and other commodities that are seasonally produced, price discovery can facilitate the carrying of inventories. For these commodities, producers, inventory holders, and speculators interact to form forward prices based on expected supply-and-demand conditions and on current supplies to ensure that existing stocks are rationed,throughout the year.

Integrating commodity production and marketing. Producers and other market participants can use futures prices as a guide for decisions about production and marketing. Using current futures prices as expectations of subsequent cash prices, they can allocate their resources to what they perceive as their most productive activities.

Futures prices can also be used in conjunction with other marketing arrangements to establish cash prices for commodities to be delivered or received in the future. A flat-price contract based on the futures market price for later delivery is one such mechanism. More commonly,

cash prices are tied by a fixed differential to the futures price at maturity.

Risk management. A closely related function provided by futures markets is shifting the risk involved in owning a commodity. Owners run the risk that its value will decline; purchasers of inputs are concerned that their prices may increase. Trading activities through the use of futures contracts and options provide producers and marketing firms with the opportunity of reducing the riskiness of their operations. These markets allow producers and merchants to reduce the effect of price fluctuations by enabling them to establish a value for their outputs and inputs and to transfer at least part of the price risk to someone else.

Shifting risk with futures contracts is done through "hedging." Hedgers sell a futures contract if they own the commodity or buy a futures contract if they expect to purchase the commodity. For example, a producer's price of corn can be hedged by selling a futures contract. The hedge exists because the producer has opposite positions in the cash and futures markets — the producer owns corn in the cash market and has sold it in the futures market.

Because the cash and futures prices tend to move together, their offsetting positions cause the gains in one market to be close to the losses in the other. A decline in the general price level of corn causes a decline in the value of the cash inventories. This decline, however, is at least partially offset by the associated gain in the futures market because the hedger can buy the futures contract at a lower price than its original sale price.

The extent to which these activities can completely eliminate price risk depends on the difference between the expected and actual basis at maturity — the futures price less the cash price. This difference is called the basis risk. Generally, however, the basis risk is smaller than the risk associated with movements in the general level of prices, making hedging an effective mechanism for reducing the variability in returns.

Although hedging by means of futures contracts can reduce variability in the value of a commodity, it also can limit the user's ability to gain from favorable price movements. In contrast, options present the holder or purchaser of a commodity the opportunity to set price floors and ceilings, while maintaining the possibility of capturing favorable price movements.

Options contracts provide the buyer the right, but not the obligation, to buy or sell an underlying commodity for a specific price in exchange for the payment of a premium. For example, a producer can buy the right to sell the underlying commodity at a specified price. If the cash market price is below the specified price, the producer exercises his option; if the cash market price exceeds the specified price, the producer simply sells on the cash market because the option is no longer of value.

Hence, options contracts can offer an "insurance coverage" that assures specified or base prices while allowing buyers of the contract to take advantage of favorable price movements in cash markets. Like all insurance coverages, however, there is a cost. In the case of setting price floors, as the hedger increases the minimum price, the likelihood of receiving a price above the minimum decreases. As the price floor is lowered, the opportunity for receiving higher prices increases.

Financial implications. The use of futures exchanges to manage risk can have implications for the financial constraints of the producer or market participant. Trading activities can effectively stabilize income or truncate the unfavorable distribution of returns. This security in the value of the commodity can lead to increased willingness on the part of lenders to loan additional funds for operating capital or longer term investments under more attractive financial conditions.

Performance

Controversy has always surrounded futures markets and their impact on other markets and prices. Questions about how well they perform their economic functions, their effect on cash prices, and their contribution to society's welfare are frequently raised by producers, politicians, and academicians. Here, we concentrate on the ability of these markets to incorporate information in price discovery and their usefulness in reducing risk.

How accurate are the markets' forward prices? How appropriately and quickly do futures markets incorporate new information? Do opportunities for speculative profits over extended periods exist? These questions have been the

subject of numerous research investigations. The results are somewhat mixed but indicate the potential usefulness of these markets in setting forward prices.

Forecast accuracy. The accuracy of forecasting subsequent cash prices by futures markets improves as the time horizon of the forecast shortens, that is, when closer to maturity. In a relative sense, futures market prices for grains, soybeans, and other semistorable commodities appear to be better forecasters than livestock futures markets.

Recent work on the relative forecast accuracy of livestock futures markets suggests that futures markets do a good job of forecasting for short horizons. For longer horizons from 4 to 6 months, research indicates that this market is not effectively incorporating all available information, especially for hogs.

As might be expected, during unstable periods, futures markets are not as effective in forecasting subsequent cash prices. But evidence suggests that it is difficult to generate statistical models that outperform the market in these unstable periods.

Effectiveness at registering and disseminating new market information. Prices in agricultural markets are highly interactive, yet examination of lead-lag relationships between futures and cash markets suggests the importance of the futures markets in short-term price discovery. Often, the highly organized futures markets are the first to register new information. Changes in prices are then effectively transmitted to the cash markets with only short delays. Recent work in the hog markets suggests that futures markets respond rapidly to unanticipated changes in market information.

Effectiveness of futures markets and options in reducing risk exposure. Several empirical studies have examined whether hedging, primarily by agricultural producers and first handlers of the commodities, reduces risks while maintaining income levels or if it increases income without increasing risks. Simple hedges reduce risk but frequently at the expense of income-generating opportunities. But more sophisticated hedging strategies that focus on locking-in only profitable alternatives have shown to be useful in reducing risk while maintaining acceptable income levels. Recently, hedging strategies based on effective forecasting techniques have resulted in even more attractive market returns.

The limited work on the effectiveness of options in reducing exposure to risk suggests that the largest benefit from hedging with options stems from the numerous risk-return combinations available. These different combinations can be created by varying the price floors or ceilings, timing, and other factors of the hedge. The mere existence of increased hedging opportunities has been shown to be beneficial to the agricultural industry.

Futures markets improve the scope and flexibility of decision making for a firm. They serve a useful economic purpose and continue to exist because of support from commercial firms that need to manage risks and make decisions. Futures markets are a facilitating and coordinating market mechanism for decision making, price discovery, risk management, and the collection and interpretation of information necessary in the allocation of scarce resources. Their importance to effective decision making in the agricultural sector is difficult to overstate.

Philip Garcia, professor; Raymond M. Leuthold, professor; and Robert J. Hauser, associate professor, Department of Agricultural Economics

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A Tribute

Raymond G. Cragle
1926-1989

Raymond G. Cragle, professor of animal sciences and international agriculture and former director of the University of Illinois Agricultural Experiment Station (1978-1983), died in Peshawar, Pakistan, on June 30, 1989. Cragle, 63, was working there at Northwest Frontier Province Agricultural University (NWFP Agricultural University) for the U.S. Agency for International Development, the University of Illinois, and Southern Illinois University. He was team leader of the Transformation and Integration of the Provincial Agricultural University Network (TIPAN) project.

Cragle's colleagues may use many words to describe his life, but they all sum up his achievements in the same way: Cragle was a dedicated, innovative, and intense individual. He was a visionary, a catalyst, a man devoted to excellence.

"His greatest quality was his single-minded determination that change could be affected in a very tradition-bound society," said Thomas McCowen, associate director of International Agriculture at the University of Illinois at Urbana-Champaign. "He always believed the best instincts of people would cause them to work together to solve common problems. He felt agriculture was basic to the development of any country, whether this one or a developing nation."

At the time of his death, Cragle was applying his vision and energy in Peshawar, Pakistan, where he "tried to apply both science and the interpersonal management skills that he had acquired to help in the transformation [of NWFP Agricultural University] into a more dynamic organization that would reach out to farmers — mostly poor farmers," according to McCowen.

"He made some major contributions in Pakistan," trying to get the NWFP Agricultural University to adopt the philosophical approach of the land-grant mission — bringing together teaching, research, and extension, said William George, currently an associate dean and director of resident instruction in the College of Agriculture. According to George, who spent a month with Cragle in Pakistan in 1986 and had worked with him when he was at the Illinois Station, Cragle was concerned about doing something for diverse groups of people — farmers, commodity groups, ag groups, and faculty.

He had great empathy for the users of research information. He felt that researchers themselves were the best ones to integrate their knowledge and the results of their research into useful applications, so he urged the faculty to think in terms of solving problems, not in terms of supplying unintegrated information.

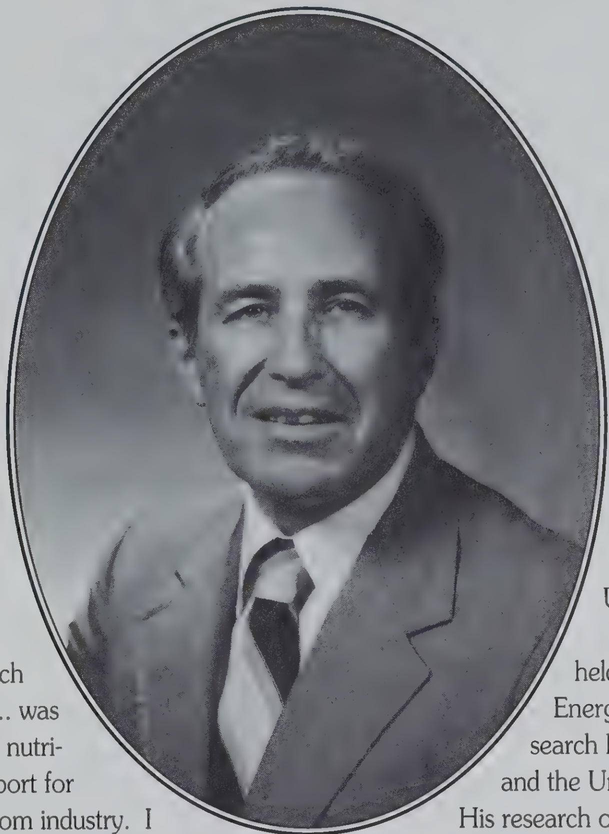
Harvey Schweitzer, assistant director of the Station, remembers Cragle as being "tremendously courteous. He had an ability to handle difficult situations and assignments.

"He was always thinking of ways to improve the Station. He encouraged departments and researchers to seek outside funding to support Hatch money." (The Hatch Act of 1887 authorized a system of experiment stations to be set up in land-grant colleges.) One of his lasting contributions to the Station was a plan for future outlying research and demonstration centers. The study he led still provides the basic framework for our field research.

Cragle can also be remembered for establishing a structure to provide leadership and direction for programs at the Station so that it could determine what programs to support, according to Douglas Bauling, assistant to the director of the Station.

"The Station identified water quality and erosion as important areas of research, and it turns out that those issues are important today," Bauling said. "Ray was never one to avoid controversy. You can't fault him for not trying — he put a lot of effort into everything he did."

Glenn Salisbury, who was Cragle's predecessor at the Station and also Cragle's teacher at the University of Illinois had this to say about him: "I heard about a young man finishing a master's degree who was well-trained in biological statistics and wanted to work with me. I was head of the Department of Dairy Science. He was an outstanding dairy student. I was impressed with him as a youngster — as a young man. He had lots of ambition, lots of promise."



Arthur Siedler, head of the University of Illinois Department of Food Science, is grateful that Cragle was such a leader: "One of [his] contributions ... was developing a food science and human nutrition funding drive that resulted in support for these programs ... some $300,000 from industry. I felt he understood research and was a strong proponent of its development."

Gary Rolfe, who was assistant director at the Station under Cragle and now the head of the Department of Forestry, remembers Cragle as "one who truly worked toward modernization; for example, he wanted more computerization, computer systems for information bases."

Rolfe recalled that Cragle hired a designer to develop the office into a more efficient and pleasant working place for his staff, a move that invited criticism, "because we all got new furniture."

Rolfe said, "He truly cared about people and was supportive. He was very interested and concerned about understanding everyone's position, although some didn't think so. He served as a catalyst to make things happen. He was a man before his time in many ways."

Staff members of *Illinois Research* especially remember this intense, energetic person for commissioning the quarterly's new design and for hiring a half-time graphics director. Every issue carries this quotation from Cragle, which embodies his philosophy and that of the Station: "At a time unlike any in the past, we must envision the future."

Cragle received his B.S. in 1951 and his M.S. in 1954 in Animal Industry from North Carolina State University. He earned his Ph.D. in Dairy Science from the University of Illinois at Urbana-Champaign in 1957.

He returned to the University of Illinois in 1978, as director of the Station. Before that, he was head of the Department of Dairy Science at Virginia Polytechnic Institute and State University from 1970.

In the 12 years preceding 1970, he held a joint appointment at the Atomic Energy Commission's Agricultural Research Laboratory in Oak Ridge, Tennessee, and the University of Tennessee at Knoxville. His research on dairy cows during this period included physiology and nutrition; metabolism of fission products; the effects of lethal and sublethal gamma and neutron radiation; mineral metabolism; the gastrointestinal absorption and secretion of mineral elements; chimerism in large animals (creating individuals containing cells derived from different zygotes); and kidney transplants and skin grafts in chimeric cattle.

Cragle was a member of the American Dairy Science Association, the American Society of Animal Science, the American Institute of Nutrition, the Transplantation Society, the Society for the Study of Reproduction, and the American Association for the Advancement of Science.

He was named as an Outstanding Educator in America in 1971. He has also been recognized in *American Men and Women of Science, Leaders in American Science, Who's Who in the South and Southwest,* and *Who's Who in America.*

He was also very active in the Presbyterian Church and the Boy Scouts of America.

Born in Orangeville, Pennsylvania, Cragle is survived by his wife, Phyllis; three children, daughter Donna and sons Mark and Matthew; three grandchildren; and two brothers, Edward, of Millville, Pennsylvania, and Larry, of Forty Four (Izard County), Arkansas.

Benjamin A. Jones, Jr., associate director of the Illinois Agricultural Experiment Station

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In Progress

The Chinese Pigs Have Arrived!

After 10 years of planning and preparations, the Chinese forerunners of what is hoped will be a breed of "super pigs" finally arrived at the University of Illinois College of Agriculture on July 27, 1989. The 46 animals are part of a research project that could have a $78-million positive impact on Illinois pork producers.

According to David G. McLaren, the assistant professor of animal sciences who heads the project, the animals resulting from selective breeding with the Chinese swine are to have the best traits of the Chinese breeds and certain U.S. breeds: the super pigs would breed as early, have litters as large, and be as docile and hardy as the Chinese animals, but they would produce meat at least as lean as that produced by current U.S. swine breeds.

The Chinese breeds being studied are too fat for U.S. markets. Porcine somatotropin, a recombinant growth hormone, however, may be useful in reducing the fat in offspring of these pigs. University of Illinois studies have indicated that somatotropin can reduce carcass fat by up to 40 percent in market weight hogs.

The 46 Chinese pigs are the University of Illinois's share of the 140 swine imported this spring from the People's Republic of China. The others were sent to Iowa State University and to the U.S. Department of Agriculture (USDA) Meat Animal Research Center in Nebraska. All of the pigs spent their first 120 days in the United States in quarantine at a USDA facility in Florida. The University of Illinois's 21 Meishan gilts and 10 Meishan, 8 Fengjing, and 7 Minzhin boars will be studied in a $1.75-million facility completed earlier this year. McLaren estimates that the University of Illinois's share of transportation and related costs for the pigs will be $500 thousand and that it will require about $1 million over 5 years to operate the research project, which will involve over a dozen researchers.

This project could dramatically affect pork production in Illinois. The average litter size of the imported Chinese sows is 15 piglets; U.S. sows average considerably less. Improving the average number of pigs weaned in U.S. litters from 8, the current size, to 11 could save producers an estimated $9 per pig produced. Given that Illinois annually produces about 8.7 million pigs, this savings means an additional $78 million for Illinois producers.

But, they should not expect to see the progeny of these Chinese pigs on Illinois farms in the near future. The study will take an estimated 5 to 10 years, and it will be at least 5 years before any of the Chinese pigs are sold to commercial producers.

The only place outside of China that these breeds have been studied is France. According to McLaren, data from that project suggest that our breeding efforts may be successful: a sow that is only half Chinese and half Large White is still as prolific as the full-blooded Chinese sow.

McLaren has noted that it is important for U.S. pork producers to improve efficiency: " Poultry consumption has doubled in this country since the 1950s, in large measure due to more efficient means of production. U.S. farmers must produce pork more efficiently in order to keep pork competitive. The research on these Chinese swine could help U.S. producers do just that. □

One of the Chinese swine that will be bred by University of Illinois researchers to create "super pigs" which will produce lean meat and numerous offspring.

Newsletter Focuses on the Ecology and Sustainable Agriculture

"Agro-Ecology news and perspectives," a bimonthly newsletter, will debut in September. In each issue, faculty from the College of Agriculture and a guest writer will address the physical, biological, socioeconomic, and political aspects of Illinois agriculture within the context of ecology and sustainability. The newsletter will keep readers abreast of agricultural issues, research and educational programs in the College of Agriculture, and upcoming conferences, workshops, seminars and lectures.

To receive a free copy, please write:
The Editors,
AGRO-ECOLOGY
news and perspectives
College of Agriculture
211 Mumford Hall
1301 West Gregory Drive
Urbana, Illinois 61801

New Directory To Link Growers to Markets

Low commodity prices in the 1980s have made diversifying farm production with alternative and specialty crops more appealing. Along with carefully researching the details of growing one or more of these crops, Illinois producers need to analyze marketing factors, such as where to sell the crop, how to locate potential buyers, and how to set the product's price. Grain farmers, livestock producers, and landowners who have had difficulty in finding markets and establishing prices for these crops should watch for the release this fall by the Illinois Cooperative Extension Service of a marketing directory for alternative and specialty crops.

To help them identify opportunities for these crops and find access to the marketplace, this directory will inform growers how to establish initial contacts with buyers and acquaint growers with the pricing, packaging, and quality standards of different crops.

The South Water Market in Chicago.

One section, for instance, will list major produce markets in the St. Louis and Chicago areas and in various locales throughout Illinois. In addition to providing a buyer's name, address, and telephone number, each entry will indicate that buyer's desired specialty crops, unusual requirements, or other relevant marketing information.

Another section will give practical information about produce items, detailing federal quality and condition grades; quality characteristics that have commercial relevance; storage, handling, packaging, and shipping suggestions; and typical harvest periods. A description of seasonal price fluctuations over several years will accompany each crop.

A glossary of marketing terms, a list of food processors in Illinois and accessible areas in adjoining states, and a table of average net weights for different packaging containers will be included. Together the sections will constitute a powerful resource for Illinois growers who are examining the possibility of setting aside some acreage for specialty or alternative crops.

The directory will be available later this year. Address inquiries to Gail Snowdon, Office of Agricultural Communications and Education, 55 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801; (217)244-2835.
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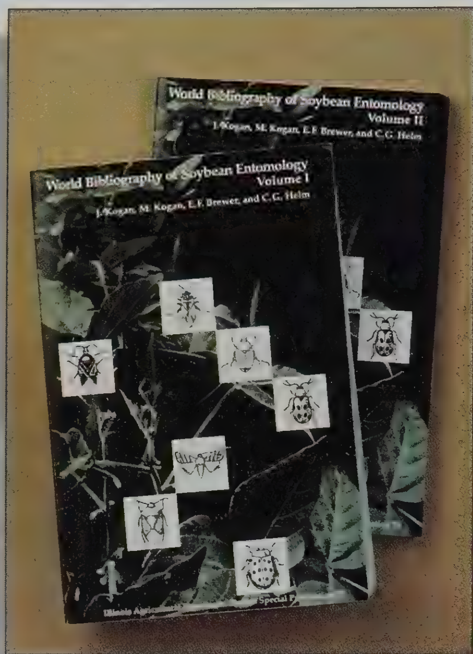

Station Publications Recognized

Once again, several Illinois Agricultural Station publications have earned national, international, and local recognition. In June, the *World Bibliography of Soybean Entomology* by Jenny Kogan, Marcos Kogan, Ellen F. Brewer, and Charles G. Helm received the 1989 Eunice Rockwood Oberly Memorial Award at the annual conference of the American Library Association.

One of only two U.S. awards for bibliographies, the Oberly biannually gives national recognition to a bibliography in an agricultural or related science. Bibliographies are judged for their accuracy, scope, usefulness, format, and special features, including explanatory introductions, annotations, and indexes.

The culmination of 7 years of painstaking research, the *World Bibliography of Soybean Entomology* provides over 25 pages of introductory material. Six indexes in a second volume facilitate access to its over 5,000 entries. To order a set, write to Publication Sales, University of Illinois Office of Agricultural Communications and Education, 69 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801. The telephone number is (217)333-2007. Each two-volume set is $65.

The University of Illinois Office of Printing Services has informed us that it has been cited for printing excellence this spring and summer for its work on *Illinois Research*. The production and printing of the issues on the centennial and the human environment (Vol. 29, No. 4/Vol. 30, No. 1 and Vol. 30, No. 2) earned first-place awards from the In-Plant Management Association and the Champaign-Urbana Ad Club.

Judging criteria for the first award included printing definition, ink coverage, register, design, typography, degree of difficulty, and overall excellence. Entries by Canadian and Mexican printers competed with those submitted by U.S. printers for this award.

The same two issues won local recognition from the Champaign-Urbana Ad Club in the category of Best Public Relations — In-House Journals. Printers and ad agencies from Champaign, Urbana, and other nearby communities submitted hundreds of entries for media and publications work done for local businesses and institutions.

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From Our Mouse to Your House: The New Look of *Illinois Research*

After receiving the last issue, several of our readers have commented that they liked the illustrations and graphic treatment, which are part of this quarterly's new look. Because of these comments, we thought you might appreciate seeing how the magic of desktop publishing *Illinois Research* works.

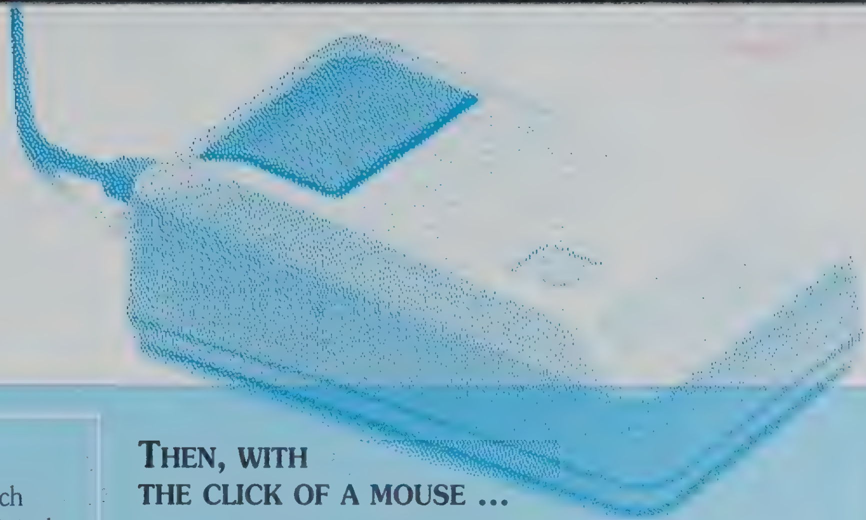
Since our graphics director, Paula Wheeler, replaced her drawing board, triangles, and pens with a Macintosh computer in February 1986, she has kept informed about the latest updates in software programs and hardware and has explored the limits of this new technology.

The current issue, for instance, was produced on an Apple Macintosh IIcx, with an 80 meg internal hard drive, 4 meg of RAM, and a Radius single-page display monitor. The following chart shows the flow of graphic production for this issue.

The desktop approach to publishing has eliminated the true galley stage along with the pain formerly associated with making corrections and adjusting the layout. Illustrations and screens no longer have to be stripped into the paged negatives

by the printshop. Eliminating conventional typesetting, paste-up, and some of the stripper's hand work has facilitated the production and printing that bring *Illinois Research* from our mouse to your house.

The editor



File conversion

IBM WordPerfect 4.2 files are converted on 3 1/2-inch high-density disks at Wheeler's workstation into Macintosh Microsoft Word format, using the Apple File Exchange utility and a MacLink Plus translator.

Then, with the click of a mouse ...

Illustrations

Wheeler generates full-color process drawings and charts with AppleScan, Claris MacPaint, Adobe Illustrator 88, and Cricket Graph. Then, she saves them in MacPaint, PICT, or encapsulated PostScript (eps) format for importing, sizing, and modifying in the paged document.

Importing text

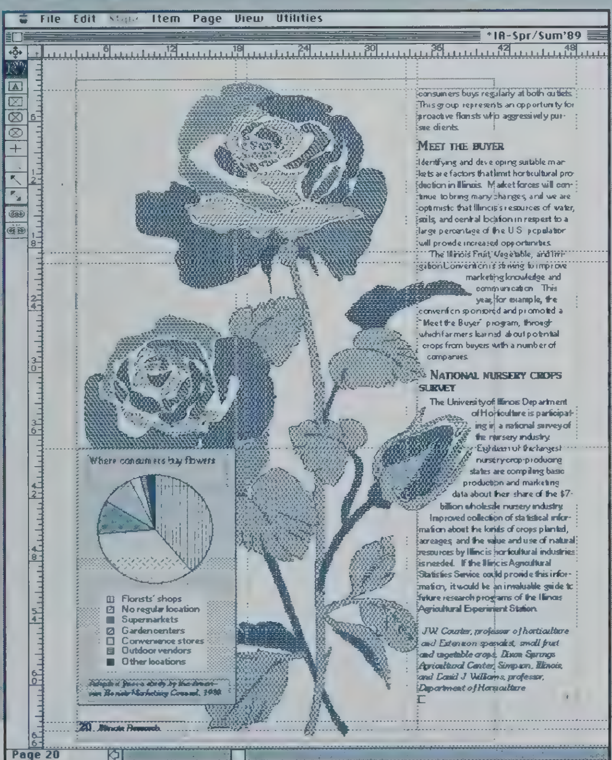
QuarkXPress, a sophisticated page-layout software program, is used to format the text in Souvenir typeface. Body copy is 10.5 point size at a 90 percent "horizontal scale" (width) with 13.2 point leading in a grid of three 14-pica-wide columns. Wheeler runs the spell checker and indicates preferences for hyphenation and other parameters. She saves a lot of time also by using text style sheets. Character spacing is adjusted by "tracking" entire groups of words or "kerning" between individual letters.

Photographs

Photos get special treatment. They are surrounded by a 1.2 point frame and have a 38 percent black screened shadow box. Portraits have windows inside oval frames created directly in the page layout. The printed frames also serve as the keyline for final slide placement. For the sake of better quality and computer memory, however, the printshop separates the final color slides and inserts the negatives into position.

Backgrounds

Graduated color backgrounds are created in a full-color process, using Adobe Illustrator 88. These blends are saved as eps and then imported into the page for placement and sizing. QuarkXPress excels in controlling both detailed color separations and complicated screen combinations.



Rough layout

Imported graphics magically meet the text in QuarkXPress. Images are sized and placed directly onto the page for a preliminary layout. Many versions of the layout may be explored before the final order of the articles is selected. Page proofs are produced with an Apple LaserWriter Plus, a 300-dots-per-inch (dpi) printer. Thumbnails are also printed to show the balance among the text, graphics, screens, and color. Corrections are then easily made, and final layout determined.

Camera ready and more!

Professional camera-ready artwork is prepared on disk and sent for Linotronic output with a resolution of 1,270 dpi. By placing all the illustrations and separating the colors herself, Wheeler has also eliminated some of the hand work formerly done by the printshop. Each of the color plates is delivered to the printshop in the form of film negatives with illustrations, reverses, screens, registration marks, and crop marks — all in position.

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SUSTAINABLE AGRICULTURE

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Agricultural Experiment Station
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Sustainable Agriculture

College of Agriculture, University of Illinois at Urbana-Champaign. Volume 31, Numbers 3/4

The Cover

Wetland at the Brownstown Agronomy Research Center.

"At a time unlike any in the past, we must envision the future."

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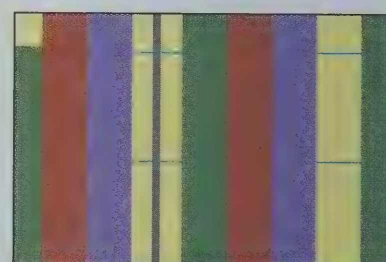

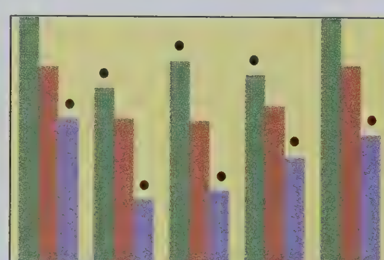

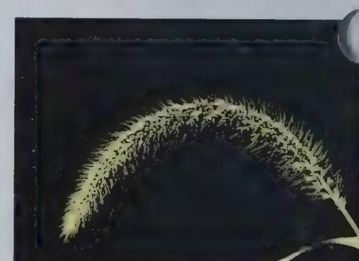

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Sustainable Agriculture: Emerging Technologies and Practices

Harvey J. Schweitzer

Anyone involved in farming, agribusiness, agricultural education, or related research is well aware of the dynamic nature of agriculture. Within a century, American agriculture has progressed from dependence on horsepower and human labor to become a highly industrialized sector of our economy. American agriculture has moved rapidly through a mechanical age and a chemical age and has now entered a biological and ecological era.

Along the route, there have been great changes in farming practices, markets, and farm policies. The impacts upon families, communities, and the environment have been dramatic.

Most agricultural changes evolve gradually. During certain periods, however, wars, depressions, scientific discoveries, and international developments have given rise to rapid change. Today a rich diversity of practices, enterprises, and values comprise the entire spectrum of American agriculture, as the old and the new are combined.

This issue of *Illinois Research* features many of the ideas, practices, and philosophies emerging in agriculture. Sustainable agriculture is difficult to define. Perhaps it can be understood most easily by examining specific technologies and practices that can be seen, measured, and evaluated. This issue describes several of these more tangible components. Sustainable agriculture can be understood, also, in terms of an overarching philosophy, which likewise emerges in the articles by University of Illinois researchers and educators.

The value of devoting an entire issue of *Illinois Research* to sustainable agriculture is in calling attention to the tip of an iceberg best described as an ecological and environmental perspective now beginning to permeate production agriculture, its related businesses, and its research and education enterprises. This perspective is tempering but not displacing the forces of competition, profitability, and production in agriculture and introducing a sensitivity to the human relationship with the land and all living things. It is alerting us to ethical issues in agriculture, relating agriculture to the larger society, and defining our concepts of responsibility to humans and nature.

The articles in this issue are indicative of the interests and capabilities of many University of Illinois College of Agriculture researchers and educators who are dedicated to an environmentally sound, sustainable, and productive agriculture.

Harvey J. Schweitzer, professor emeritus of agricultural economics and former assistant director, Agricultural Experiment Station

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A field at the Orr Agricultural Research and Demonstration Center.

Can Sustainable Agriculture Sustain the Farm Family?

John C. van Es and Robert J. Reber

In the 1987 Census of Agriculture, Illinois had 88,786 farms, about 150,000 fewer than in 1920. One main reason for this change was that a technology dependent on fossil fuels had been substituted for labor on the farm.

The continual introduction of technology has resulted in both an increasing production and a persistent squeezing of the profit margins of individual farmers. To attain a standard of living comparable to that of nonfarming citizens, many farmers joined a rapidly growing urban labor force, or at least encouraged their children to do so. Those remaining on the farm pursued a strategy of growth, increased use of technology, and greater production in a relentless struggle to survive in a world of small profit margins.

Changes

The consequences of the changing farm structure for farm families and rural communities are well known. Farm families frequently found themselves under great stress as they tried to adjust to economic forces beyond their control. Although certainly not all departures from farms were associated with extreme hardships, enough cases have been documented in research studies, literature, and films to etch a picture of the American farm family as caught in a losing battle to save its way of life.

Many rural communities, too, have suffered the consequences of the agricultural transformation. The loss of farms made it difficult to maintain businesses serving agriculture; fewer residents led to closing or consolidating rural schools, hospitals, and churches. People remaining in the rural community often found (and continue to find) it impossible to satisfy their economic, social, and cultural needs locally.

For those remaining on farms, life has frequently been stressful. The normal insecurities of farm life, such as weather and crop disease, have been intensified by worldwide economic developments. For example, untimely rainfall in Brazil or the size of the federal deficit influences the year-end profit statement. Finally, health and safety concerns and environmental problems associated with modern farm technology and practices are forcing farm operators to confront very difficult choices from limited options.

Much of the current effort to create a more sustainable agricultural system has its basis in attempts to deal with the health and safety concerns, environmental degradation, and economic failures associated with modern farming practices. Yet, the changes in agriculture go far beyond these issues, to include the decline in the number of farms and the decline of rural communities, especially those that are agriculturally based. Until now, the attempts to create a sustainable agriculture have paid too little attention to how this approach might affect the individual farm unit's sustainability or the viability of the agriculturally based community. The following section touches on some of the social aspects of sustainable agriculture: (1) the family decision-making issues and (2) the relationship between the sustainability of the individual farm unit and the rural community.

Decision Making

On the family farm, both husband and wife are actively involved in decisions to keep the farm economically productive, and in decisions about teaching and rearing the children. The discussions on sustainable agriculture emphasize the interconnectedness of the different parts of the biological, economic, and physical system. These discussions, however, rarely go beyond the treatment of the farm as a production unit dominated by the (typically, male) farm operator.

But, according to research, both spouses traditionally have had their own spheres of responsibility and authority, which together constitute the family farm. For example, the male makes most decisions about routine purchases of farm supplies, is responsible for most field and animal work, and supervises hired help. The female typically takes major responsibility for the family's well-being, including nurturing and rearing the children. Additionally, she may do some or all of the farm record keeping. However, husband and wife may jointly decide major farm changes, such as borrowing money for buying land or switching from a specialized grain operation to a more diverse farm management scheme that introduces complex rotations among various crops and livestock enterprises.

The farm wife's traditional responsibility for health and safety issues and her participation in decisions about major

changes in farm enterprise activities make it likely that women will play a significant role in the transition to a sustainable agricultural system. Yet, until now little was documented about women's influence on decisions to shift the farm operation to a more sustainable approach.

Income

Another way in which farm families are likely to play an important role for sustaining the individual farm unit relates to the families' ability to attract nonfarm resources to support the farm household. If sustainability is to include the continuation of many smaller and medium-sized farms — a goal often expressed by advocates of sustainable agriculture — any plan must include consideration about sources of off-farm income that some units may require.

Unless significantly higher profit margins are maintained, which is not likely in a world economy, operators of smaller enterprises will find it difficult to support adequate living standards. Sustainable agriculture as envisioned by some will not likely change that situation. Under these economic conditions, a system that sustains individual units may depend on the community's providing off-farm employment for members of the farm household. Without such support, the survival rates of smaller units may not improve.

The dependence of the farm household on off-farm income also indicates that any system of sustainable agriculture must accommodate the farm labor demands on the household to meet off-farm income needs. Whether it is the wife, the husband, or both who take an off-farm job is probably not important as long as the household can meet the labor demands both on and off the farm. Because many proposed systems of sustainable agriculture appear to be more labor intensive than conventional systems, accommodating labor demands may become a significant issue.

Benefits

Although individual farms may still depend on off-farm income, the widespread adoption of a sustainable system will provide benefits to the local community, as will the decrease in environmental degradation. The increased variety of agricultural practices in a sustainable system should insulate the individual farm and the local community from the large economic swings that often accompany a highly specialized system.

Increased agricultural diversification and greater attention to conservation practices such as the use of cover crops and shelter belt plantings could generate additional benefits to the community: for example, a more pleasing countryside aesthetic and an increased biodiversity of both game and nongame species.

Making agriculture sustainable environmentally and economically does not necessarily imply that individual farms will more likely survive in a competitive market environment. If maintaining many farms is a desired outcome of a shift to sustainable agriculture, planners must be more cognizant of the social basis of sustainable agriculture. Developing supportive relationships between the farm enterprise, the farm household, and community resources will be necessary if sustainable agriculture is to include sustainable family farms.

John C. van Es, professor of rural sociology, Department of Agricultural Economics, and Robert J. Reber, associate professor of nutrition, Division of Foods and Nutrition, School of Human Resources and Family Studies

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Economic Incentives for Alternative Cropping Systems

Earl R. Swanson and Loyd M. Wax

Economic incentives play a major role in a producer's decisions to adopt a cropping system. In this article we view economic incentives in terms of (a) average net returns over a period of years and (b) riskiness, or the year-to-year variation in net returns. A cropping system is a combination of a crop rotation, tillage practice, and level of pesticide use. Eighteen alternative cropping systems were evaluated. Without a precise operational definition of "sustainable," it is not possible to rank all 18 systems in terms of their "sustainability." Some instructive comparisons can be made, however, that indicate the strength of economic incentives in moving toward adoption of more sustainable cropping systems.

A Six-Year Experiment

A six-year cropping system experiment was conducted from 1980 to 1985 at three Illinois locations: DeKalb, Urbana, and Dixon Springs. The results of this experiment were used for our economic evaluation of cropping systems, providing a much better basis for evaluation than two other approaches commonly used.

One approach falls short because the experience of a few individual farmers using certain practices that appear to be successful may not be valid for transfer to other farmers. Even if the physical environments are similar, differences in management skills may prevent successful repetition on other farms. Another approach to economic evaluation involves the informal synthesis of results from various single-practice systems.

For example, the effect of the tillage system on crop yields is difficult to determine without knowing the crop rotation and the level of pesticide use. In short, we are dealing with an interdependent system of rotation, tillage system, and level of pesticide use. To evaluate that system's technical and economic performance, we must know something about the interactions among its components. The six-year cropping system experiment is designed to reflect this interdependence and thus provides a more reliable base for assessing effects on crop yields and, in turn, economic results.

Cropping System Components

The results of the cropping system experiment at Urbana will serve to illustrate economic evaluation of alternative cropping systems. Three crop rotations were considered: (CC) continuous corn, (CS) corn-soybean, and (SS) continuous soybean.

Two tillage systems were used: conventional tillage (CT) and reduced tillage (RT). The conventional tillage of any crop following corn involved either stalk chopping or mowing, disking and moldboard plowing in the fall, and at least two passes with a secondary tool in the spring. Following a soybean crop, conventional tillage plots were chisel plowed in the spring and received at least two passes with a secondary tillage implement. Reduced tillage following soybeans did not include any tillage in the fall but usually involved at least two passes with a secondary tillage tool in the spring. Reduced tillage following corn involved no fall tillage but at least two spring tillage passes of either a disk or field cultivator. All plots were cultivated at least once.

The three levels of pesticide use — low (LP), medium (MP), and high (HP) — were differentiated by the use of various combinations of herbicides and insecticides. LP used one or two herbicides. MP used two to four herbicides and a soil insecticide for corn. HP used three to six herbicides and doubled the MP rate of the soil insecticide.

Preplant herbicides were applied and incorporated just prior to planting, by two passes with a tandem disk set to cut to a depth of four to six inches. Preemergence herbicides were applied just after planting, with no incorporation. Early preplant herbicides were applied three weeks before planting. Postemergence herbicides were applied in most instances when weeds were three to four inches tall. All herbicide treatments were broadcast applications. Soil insecticide treatments were applied at planting.

Within each level of pesticide use, treatment amounts (rates and number of applications) varied yearly as dictated by the recent past history of pest control. Total usage and cost, however, were held relatively constant.

Effects upon Crop Yield

The experimental design makes it possible to estimate the separate influences of crop rotation, tillage system, and level of pesticide use on the per-acre yields of corn and soybeans. Figure 1 shows the

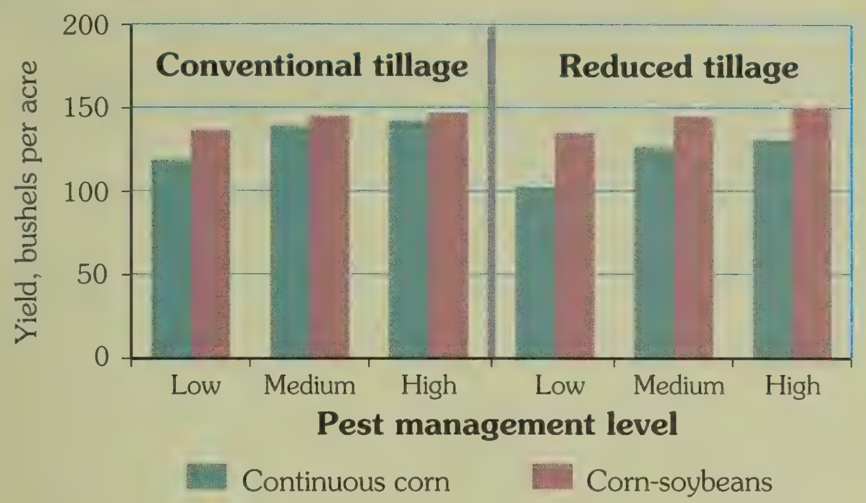

Figure 1. The effect of rotation on corn yield, Urbana, 1980 to 1985.

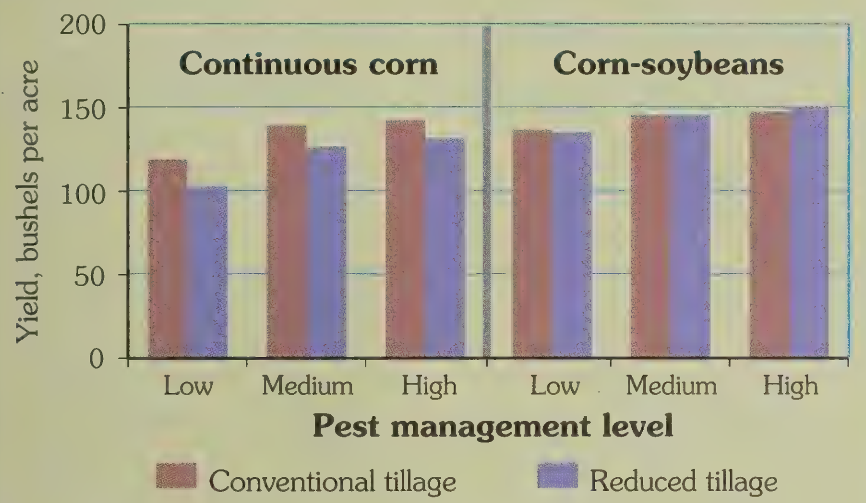

Figure 2. The effect of tillage on corn yield, Urbana, 1980 to 1985.

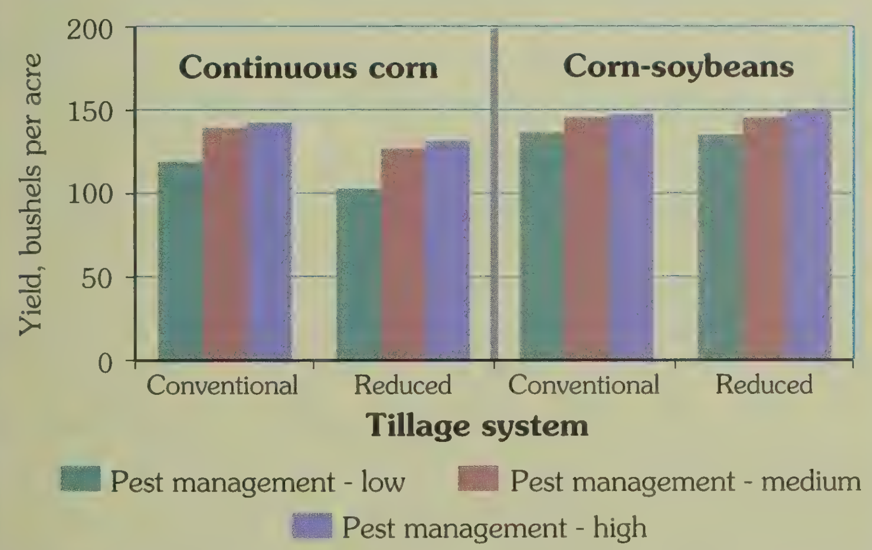

Figure 3. The effect of pest management on corn yield, Urbana, 1980 to 1985.

six-year average yields at Urbana for the two rotations of corn. Note the higher per-acre corn yields under a rotation for all levels of pesticide use with both conventional and reduced tillage. (Soybean yields displayed a similar result.)

Figure 2 shows the effects of tillage on corn yields. Under continuous corn, reduced tillage results in decreased corn yield. Yield differences between tillage methods are mixed and smaller with the corn-soybean rotation than with continuous corn.

Figure 3 shows the response of corn yields to the level of pesticide use. The yield increment from increasing the level of pesticide use from low (LP) to medium (MP) is much higher with continuous corn than with the corn-soybean rotation.

Net Returns and Risk

One reason for variation in crop yields among cropping systems is the difference in type and amount of nonland inputs. To account for these differences, costs per rotation acre were calculated and subtracted from the value of production. Average prices and costs for the six-year period were used to calculate net returns. Corn was valued at $2.50 per bushel, soybeans at $5.97. Land costs were not included because these costs are the same for each cropping system.

In Figure 4, we note a group of eight cropping systems with the highest net returns, between $117 and $133 per acre: CS-RT-MP, $133; CS-CT-LP, $127; CS-RT-HP, $129; CS-RT-LP, $119; CS-CT-MP, $129; CS-CT-HP, $118; SS-CT-HP, $127; SS-RT-HP, $117.

Six of these eight cropping systems use a corn-soybean rotation. The two continuous soybean systems achieve their high return in part due to the high level of pesticide use.

This cluster of eight cropping systems not only has high net returns but also has greater income stability than most of the other systems. The standard deviation of net returns (horizontal axis of Figure 4) is used to measure the variation in net returns. Because six-year average corn

and soybean prices were used to value crop production, only yield variability is reflected in this measure of net returns variation. The income stability in these systems is primarily due to the corn-soybean rotation. Corn and soybean yields are not perfectly correlated.

In Figure 4, the six systems with medium return and medium risk and the four systems with low return and high risk are all continuous cropping of either corn or soybeans. The four systems in the lower right-hand corner (low return-high risk) all have a low level of pesticide use.

Implications for Sustainable Agriculture

The economic evaluation presented in the preceding paragraphs is based on two criteria — average net returns per acre and the year-to-year variation in net returns per acre. How do these cropping systems rank in terms of their sustainability? In general, the reduction in soil loss that would occur in a shift from conventional tillage to reduced tillage represents a movement toward a sustainable system. Further, a decrease in the level of pesticide use might also contribute to achieving a sustainable system. From the standpoint of sustainability, it would be desirable to adopt CS-RT-LP: a corn-soybean rotation with reduced tillage and low pesticide use.

Given the uncertainties in agricultural production, one could hardly argue there is much difference in economic incentives among the eight cropping systems in the high return-low risk group. Thus, a shift to CS-RT-LP would occur for reasons other than economic ones.

One reason for the rather narrow economic differences among the eight best-performing cropping systems is the rather limited range of practices used in this experiment. For example, even the low level of pesticide use employed some herbicides. Corn and soybeans were the only crops considered; legume forage crops, for example, were not an option. Nitrogen fertilizer applications to corn were kept uniform in this experiment. Indeed, it may be premature to evaluate alternative cropping systems in terms of both economic incentives *and* sustainability until a broader range of alternative rotations, tillage systems, and pest management systems have been included in a similar six-year experiment.

Earl R. Swanson, professor emeritus of agricultural economics, and Loyd M. Wax, USDA agronomist and professor of agronomy

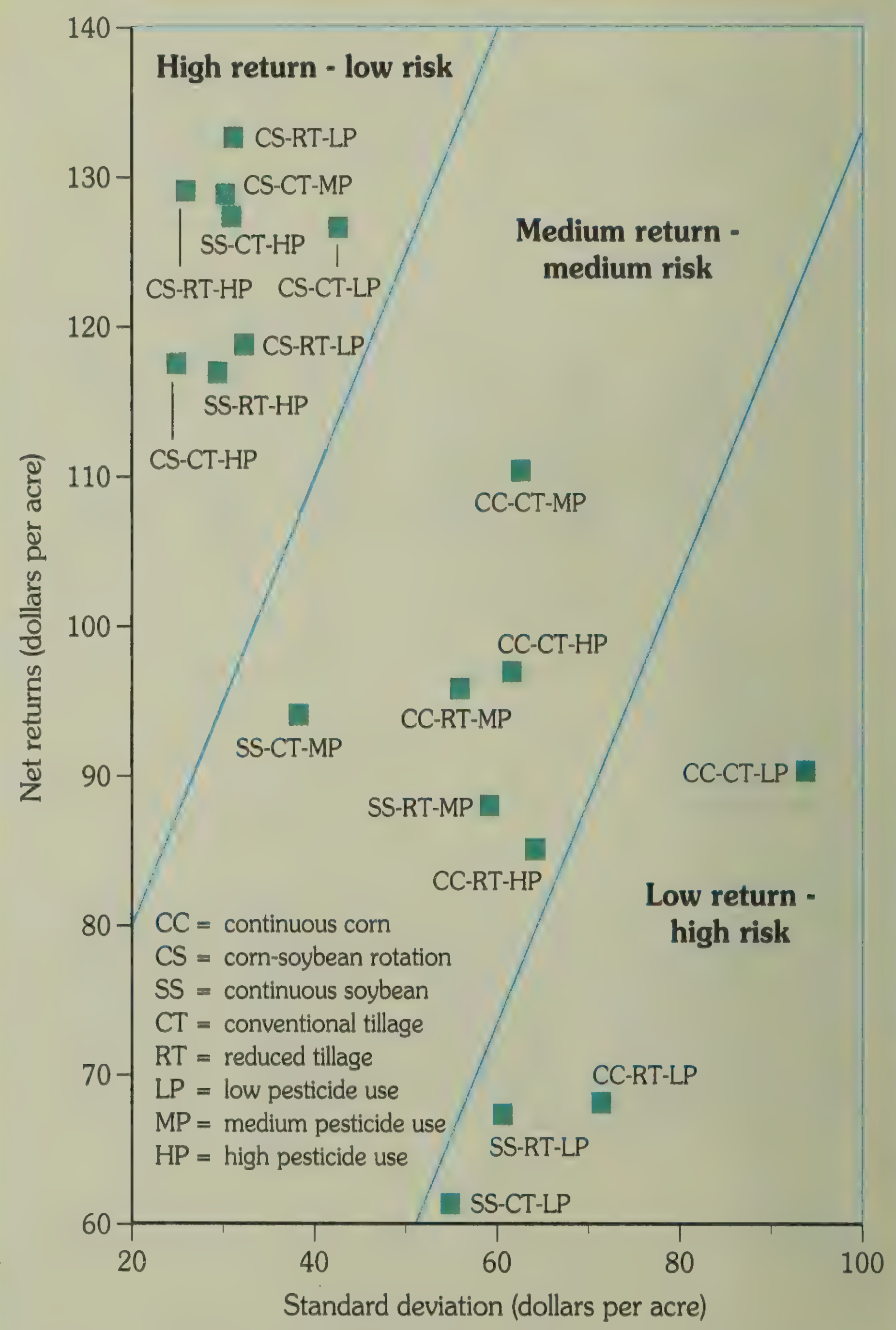

Figure 4. Cropping systems — returns and risk, Urbana, 1980 to 1985.

Policy Dimensions

Harold D. Guither

For every policy decision, there is a consequence. A policy to encourage and promote low-input sustainable agriculture (LISA) has consequences for producers, for consumers, and for agricultural business firms supplying farmers and marketing agricultural commodities. The nature and the extent of these consequences, in many cases, have yet to be determined.

Defining and understanding sustainable agriculture. To anticipate how sustainable agriculture policies can affect Illinois farms and rural communities requires that we understand exactly what sustainable agriculture is and what it is not.

A survey of Illinois agribusiness firms in the spring of 1989 revealed that only 32 percent believed they understood what LISA is, 32 percent believed that efforts to conserve resources and maintain profitable farm enterprises are a major focus, and only 10 percent believed that it would be beneficial to their business if most farmers followed the LISA program. The responses showed much uncertainty about what LISA is and how it can affect their business.

Crucial questions. The consequences of LISA will depend upon the nature of government programs and actions taken to implement a system of using fewer cash inputs in the production process. Programs that force abrupt changes in using fertilizers, pesticides, and animal health products can have immediate negative impacts upon farm production, farm incomes, and the quality of farm products, although environmental conditions may improve. Programs designed to make changes over a period of years may have little noticeable effect on total farm production, farm incomes, and the quality of farm products moving to market.

Will chemicals and fertilizers be more stringently regulated? The immediate prohibition of many popular and effective pesticides generally accepted by the most progressive producers would be disastrous. However, reducing the use of fertilizers and chemicals beyond the amounts needed for effective pest control or optimal yields could benefit producers, consumers, and the environment.

Will restrictions be mandatory or voluntary? Through the years, Illinois farmers have accepted voluntary price support and production control programs more readily than mandatory programs. Similar reactions may be expected to other proposed programs.

Farmers accept policies that they believe are in their best interest. In a policy preference survey among Illinois farmers in the spring of 1989, 63 percent believed that soil conservation and water quality compliance should be a condition for receiving farm program benefits. On another question, 62 percent agreed that the government should regulate certain farming practices and land uses to reduce pollution of underground and stream water.

What kinds of regulations will be involved? The most successful programs will offer incentives for voluntary compliance and minimal restrictions that disrupt profitable farming operations. An integrated crop management pilot program in five counties pays producers who voluntarily reduce pesticide use. The program's success, however, remains to be seen.

Harold D. Guither, professor of public policy, Department of Agricultural Economics

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A farmer applies lime to his field.

Canola: An Alternative Crop for Illinois

Emerson D. Nafziger and Robert W. Frank

Many strategies for creating a more sustainable agriculture include crop diversification. The number of crops grown on any one field in Illinois has decreased with the movement toward a more specialized agriculture; and attempts to broaden the cropping base with sunflowers, crambe, buckwheat, and other crops have not had wide success. To diversify cropping, Illinois farmers are now testing winter canola, oilseed rape genetically improved for oil and meal quality.

As an edible, oil-producing crop, canola will not always offer a clear marketing alternative to soybeans because its price will follow world oil prices. Because canola is harvested in June, however, price changes associated with the growing season for soybeans may be advantageous for canola. In the last two years, price changes have worked both to canola's favor and to its detriment. The price rose before harvest in 1988 because of the drought but fell in June 1989.

The agronomic diversity offered by canola is also somewhat limited. Although the crop is in the field for about the same period as winter wheat, it is necessary to plant three to four weeks before winter wheat, which may prevent canola from following corn or soybean harvest in most of the state. Set-aside acres or small grains work well as preceding crops. Fertility, soil, and general weather conditions that are favorable for canola are also favorable for wheat, however, and the very good wheat yields of 1989 made the wheat-canola comparison favorable to wheat. In some years the canola harvest will be a few days earlier than wheat, thus improving chances for a soybean doublecrop. Because the weather in 1989 was cool, canola and wheat were harvested about the same time, disappointing farmers expecting an early canola harvest.

Most canola varieties that seed companies sell to Illinois farmers were developed in Europe, where the crop is widely grown. Limited testing and experiences of Illinois farmers show that these varieties are fairly well suited to conditions here but will require high-yielding varieties with earlier maturity dates and improved resistance to seed shatter, disease, and lodging. Canola requires a fine seedbed and careful harvest but no special equipment. Improved weed control, however,

↑ Canola has small, round seeds that thresh easily from the pods.

Marketing Challenges and Risks of "Sustainable" Agriculture

Sarahelen R. Thompson and C. Christopher Doll

The effect on producer income of adopting low-input, or "sustainable," agricultural practices depends on how these practices affect yields, production costs, and price received per unit.

The adoption of low-input practices may result in reduced yields as compared to conventional methods. To compensate for reduced yields, producers must reduce production costs, receive a higher price per unit of output, or do both. Although "low-input" suggests lower production costs, total production costs may actually rise if more costly labor is required to replace chemical inputs. Therefore, the challenge for many producers who adopt low-input methods is to find a means of obtaining higher returns per unit of output and thus to avoid lower net returns from farming.

One way that producers may receive a higher price is by targeting production to consumers willing to pay a higher price for food produced with reduced chemical inputs. Among some consumers the growing concern about the potential health hazards to food or the environment from chemicals applied in farming makes them willing to pay higher prices for food grown "organically" or with reduced chemical inputs.

If producers hope to cash in on this market, they must tailor their production and marketing programs accordingly. They must also inform consumers of their product's availability by advertising and labeling.

is necessary: only two herbicides currently are labeled for use on canola in the United States. Seed loss during harvest can also cause canola to become a weed in most fields where it is grown.

Although prices for canola will not always be favorable, increased familiarity with the crop and further adaptive research should make it an acceptable alternative for Illinois farmers. Average yields of about 35 bushels per acre should increase as farmers gain more experience; however, farmers should keep acreage small initially to limit risk.

Emerson D. Nafziger, associate professor of agronomy, and Robert W. Frank, Extension adviser, agriculture, Jackson County

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↑ Canola's bright yellow flowers are distinctive in the spring.

↓ Because canola pods often do not ripen uniformly, knowing when to harvest may not be easy.

Unfortunately, reducing chemical inputs may reduce the product's quality, as conventionally judged. For example, fruits and vegetables produced with low-input methods may have a higher incidence of blemishes, some physical and some superficial.

If the reduction in product quality is only superficial, and does not diminish palatability, producers may still receive a reasonable return if they can induce consumers to try their product. Besides labeling such produce as "organically grown" or "pesticide free," clever marketing slogans may be used to overcome consumer resistance to blemished produce. One grower in southern Illinois has used the "kissed by nature" slogan to sell hail-damaged apples.

The marketing problem is more difficult when reduced chemical inputs significantly reduce product quality. For example, a reduction in pesticides may result in a product with more disease or insect damage. In this case, it is likely that growers will receive a much lower price or be unable to sell their output through regular markets.

Crop diversification and rotation are low-input production methods that are often suggested to spread and reduce overall risk, but these methods also result in some problems. To attract and keep customers, producers must provide steady supplies of certain crops. Producers can spread the risk of crop failure or low crop prices over several crops by producing more than one crop (diversification). To accommodate the production and rotation of a variety of crops, thereby reducing the producer's income risk and improving productivity, individual operations may have to grow in size. With each added crop, a producer's management ability in both the production and marketing areas must also increase.

Sarahelen R. Thompson, assistant professor of agricultural marketing, Department of Agricultural Economics, and C. Christopher Doll, area adviser, fruits and vegetables, Illinois Cooperative Extension Service

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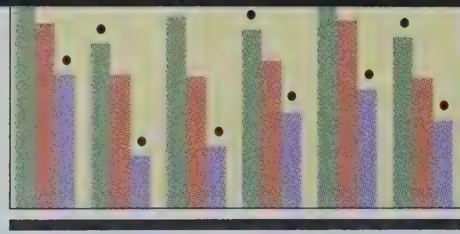


Economic Study of Efficient Reduced Input Farms in Illinois

Robert H. Hornbaker

Rural America is experiencing far-reaching problems that affect society and producers. There are growing societal concerns over environmental quality. Chief among these concerns is ground-water contamination from agricultural pesticides, herbicides, and fertilizers; but also important are soil conservation, silting in lakes and streams, odors, and worker safety.

These concerns have led to increased interest in and adoption of production practices such as reduced tillage, no till, and organic farming that diminish the potential for environmental damage. These concerns have also prompted proposals to reduce or eliminate pesticides, herbicides, and fertilizers.

Despite recent government programs and relatively strong incomes for the agricultural sector in general, a significant number of farmers and landowners are in economic distress. For these producers to remain in the agricultural sector, they will need help in identifying production practices and mix of input strategies to enhance profits.

Some groups or individuals concerned with the environment may argue that any input with negative environmental effects not be used. Others advocating maximum production may suggest application of more than the average profit-maximizing amount "in case it's an above-average year." Neither policy may be sustainable in the long run, and the first policy may not even be sustainable in the short run.

Economic Theory

In static production theory, some known quantity and mix of inputs and combination of outputs will maximize profits for a given farm. But, because biological production processes are dynamic, farmers do not face static production decisions. These uncertainties make it impossible for farmers to apply the profit-maximizing level of inputs on all their fields. Profit-maximizing levels differ by location and fields due to soil quality and climate and with changes in commodity prices and input prices. Input applications both above and below the profit-maximizing levels can thus occur, leading to reduced profits.

Figure 1 demonstrates a case where quantities of input below (q_1) and above (q_2) the profit-maximizing amount yield lower profits (π_1). In the short run, a farmer may be indifferent to these two quantities because they provide the same level of profit. However, if negative externalities are associated with the input q, quantity q_1 should be used. By using quantity q_1, the amount of input $q_2 - q_1$ is not placed in the environment and profits are sustained at the same level as with q_2. Although the farmer would like to use the level of input that provides profits of π^*, the externalities associated with some chemical inputs such as nitrogen fertilizers, herbicides, and insecticides may dictate that it is better to, on average, apply input quantities below q_1 not above.

The dynamics of production entail not only applying the correct quantity of input, but also using the proper application, timing, and procedure. Technical

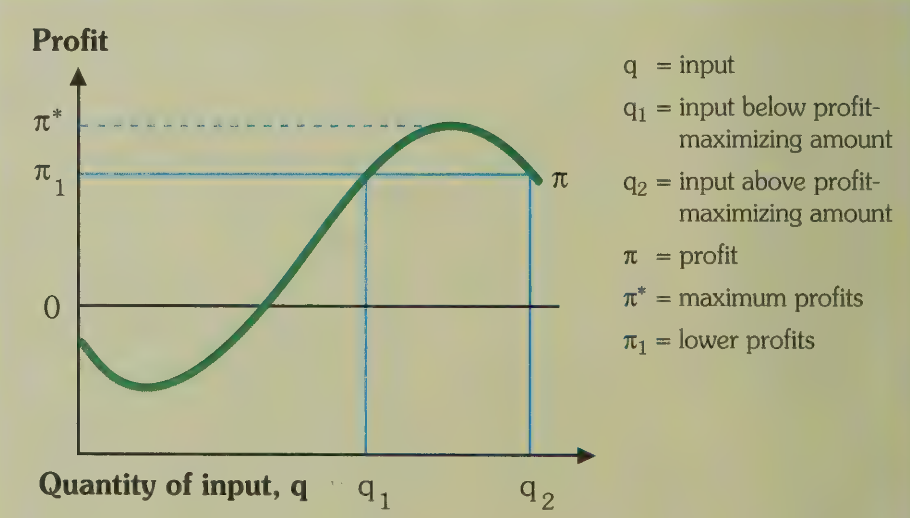


Figure 1. Profits associated with input quality.

efficiency is the management ability required to apply or implement the input quantity to achieve the maximum output for that level of input. Technical inefficiencies, at the firm level, quantify the technical management input that is not provided along with other inputs and imply that profits can be increased or input use can be decreased by improved management practices that increase production efficiency.

Empirical Analysis

The preliminary results of a study examining the economic feasibility and viability of reduced-input agriculture are presented. Using 11 years of detailed information from the Illinois Farm Business and Farm Management records, profitable reduced-input farm operations were identified. Based on their per-acre expenditures for cash inputs — fertilizers, herbicides and pesticides, seed, drying and storage of grain, fuel and oil, and hired labor — 161 farms were stratified. This analysis is based on expenditure levels rather than input quantities. Generally, there is little between-farm variation in the prices paid for most inputs. Thus, the categories of farms will be referred to as high use and low use, remembering that the levels are relative to the other farms in the sample.

Farms were divided into three groups: (1) the high-use group, the 40 farms that spent the most on cash inputs on average during the 11 years; (2) the low-use group, the 40 farms that spent the least; and (3) the remaining 81 farms that fell in the middle in terms of cash inputs. The average yearly values from this analysis are depicted in Figures 2, 3, and 4.

Farms in the study spending the highest amount on cash inputs harvested more bushels per acre, but their net income per acre was 17.5 percent less than that of farms that spent the least amount on these cash inputs. Adjusted for inflation, the high-use farms in the sample averaged $44 per acre (in 1982 dollars) for fertilizer and grossed $376 per acre. Farms that spent significantly less averaged $32 per acre and grossed only $339 per acre. The gross returns for the low-use farms were significantly lower, at the 5 percent level, in 7 of the 11 years. However, the net

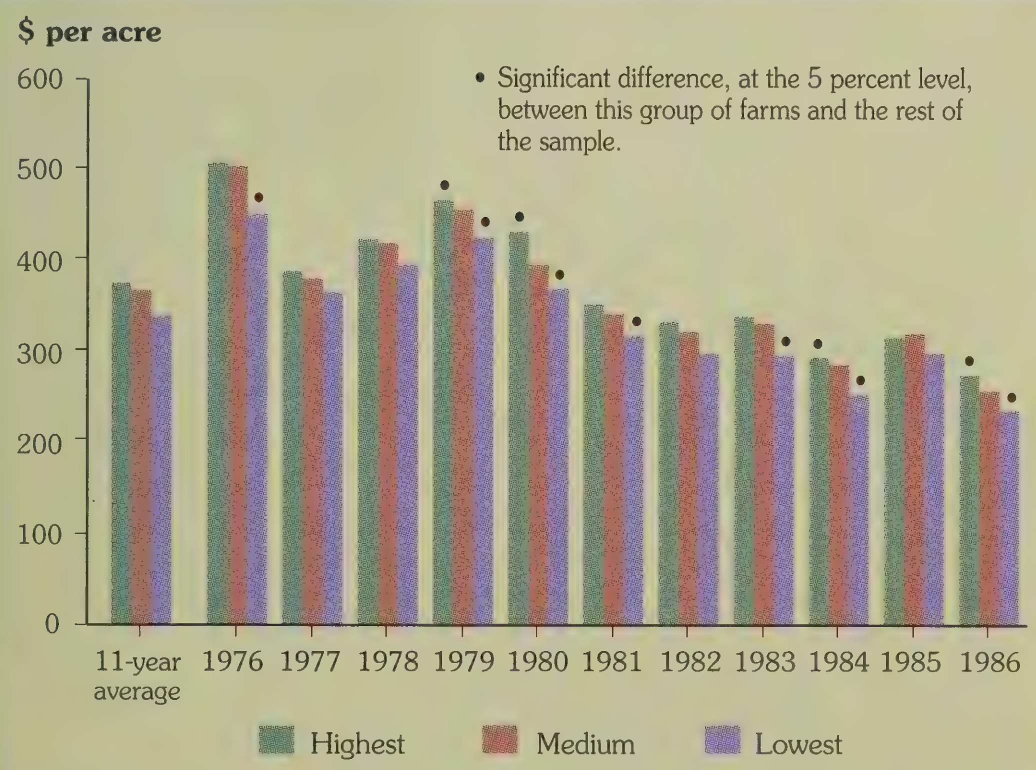


Figure 2. Average per-acre gross returns for farms categorized by the highest, medium, and lowest per-acre cash expenditures.

profit for the low-use farms averaged $165 per acre compared to only $136 for the high-use . farms over the 11 years. The high-use farms had significantly lower net farm returns at the 5 percent level in 8 of the 11 years.

As shown in Figure 4, the per-acre fertilizer expenses were significantly lower, at the 5 percent level, for the low-use farms in all years, as was the level of total cash expenditure.

These preliminary results tend to indicate that some central Illinois farms are more efficient than others, use fewer inputs, and show profits that are sustainable in the long run. Although new, improved tillage systems and crop rotations can reduce levels of input use, better management or increased technical efficiency associated with existing practices can also lead to reduced input use, sustained profits, and less damage to the environment.

Robert H. Hornbaker, assistant professor of farm management and production economics, Department of Agricultural Economics

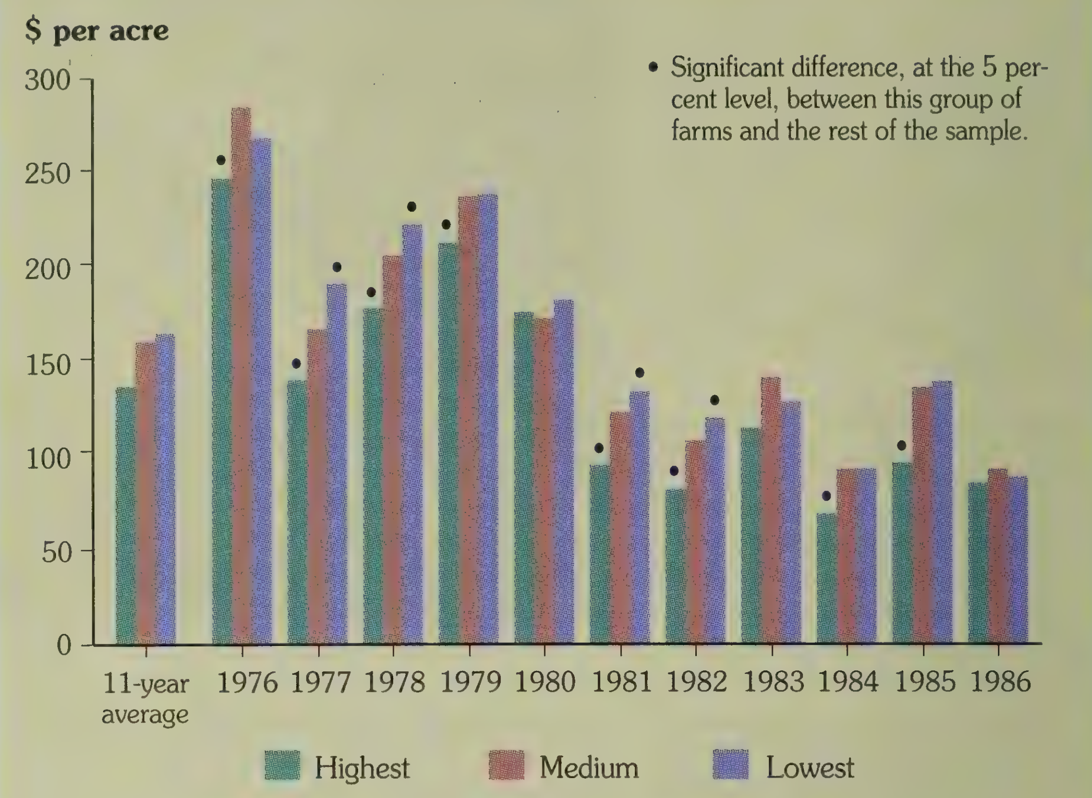


Figure 3. Average per-acre net farm returns categorized by the highest, medium, and lowest per-acre cash expenditures.

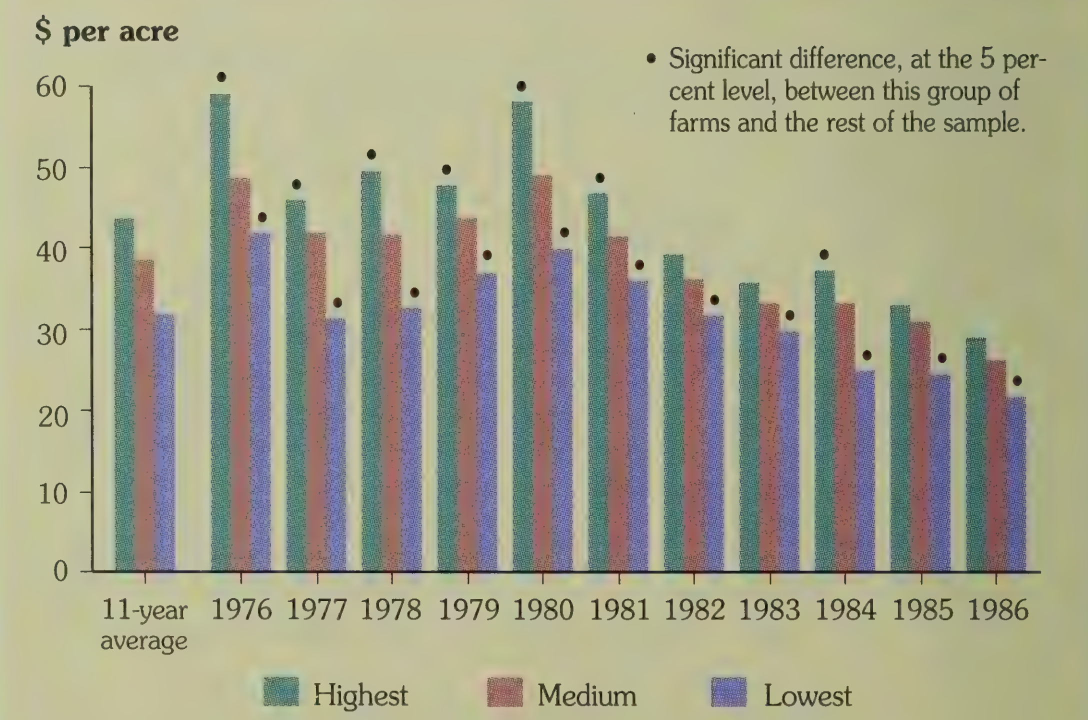
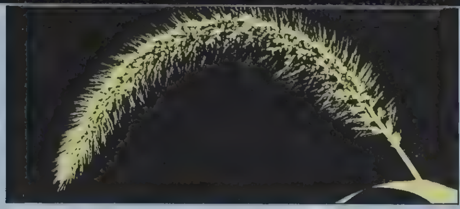


Figure 4. Average per-acre fertilizer expenses for farms categorized by the highest, medium, and lowest per-acre cash expenditures.



IPM: A Systems Approach to Sustainability

Donald. E. Kuhlman, Ellery L. Knake, Michael E. Gray, and H. Walker Kirby

Integrated Pest Management (IPM) began in Illinois in 1972 with 46 Boone County farmers in a pilot corn-pest scouting program initiated by the Cooperative Extension Service (CES) and the Natural History Survey. The next year the program expanded to include Hancock, Shelby, and Warren counties. During the 1970s, IPM's formative years, a primary objective was to demonstrate to farmers the value of scouting for insect, weed, and disease pests in field crops.

Too often IPM is equated with biological or nonchemical control, which farmers do not always readily accept. In a 1979 address to Congress, President Jimmy Carter described IPM as "a systems approach to reduce pest damage to tolerable levels through a variety of techniques including predators and parasites, genetically resistant hosts, natural environmental modifications, and, when necessary and appropriate, chemical pesticides." Basically, the IPM concept uses pest control actions that ensure favorable economic, ecological, and sociological consequences.

SA/LISA

Recently, the concepts of sustainable agriculture (SA) and low-input sustainable agriculture (LISA) have captured the attention of scientists, farmers, environmentalists, and others involved in agriculture. The definitions of SA and LISA vary, as does that of IPM; but all three concepts embrace cost-effective practices that conserve the soil and protect the environment and human health.

According to University of Illinois agronomists Robert G. Hoeft and Emerson D. Nafziger, SA is "a management system that uses inputs available on the farm and those purchased externally to obtain the highest productivity and profitability from a farming operation while minimizing adverse effects on the environment." Without question, nutrient cycling and pest management will be major components of such systems.

IPM/LISA: Revolution or Evolution?

Since 1973, IPM has attracted the support of farm organizations, politicians, environmental organizations, farmers, the pesticide industry, and agricultural colleges. But will they also support LISA, a concept that is now evolving?

As LISA and SA evolve, it is important to recall that in the 1970s the IPM concept was not well understood or accepted by some of these same groups. Many agriculturalists were suspicious of IPM. The pesticide industry feared that pesticide sales might plunge. Environmentalists viewed IPM as a system to eliminate or reduce pesticide use. University researchers and Extension staff, always cautious, saw a need for IPM but were sometimes reluctant to proceed without a large research base. The farmer was bewildered, perhaps even amused, by efforts of university staff to introduce new concepts for pest control: pest scouting, economic thresholds, biological control, and more judicious use of pesticides. A common belief in the early 1970s was that pest control with pesticides was working, and there was no need for change.

Objectives

University of Illinois scientists William H. Luckmann, Howard B. Petty, Robert L. Metcalf, and Stevenson Moore III were strong advocates of IPM in its early years. Despite the need for chemicals to control pests, the scientists sensed an urgency for farmers to adopt IPM systems due to pesticide-resistant pests, increasing costs of petroleum-based pesticides, environmental contamination, adverse effects on human health, and ecological disturbances — all consequences of the injudicious use of pesticides.

Today, concerns about groundwater quality, pesticide residues in food, and the health and safety of producers and consumers will likely increase even more. The public will expect leadership and vision in addressing these complex issues.

The components of IPM seem ideally suited for use in SA systems. IPM practices can minimize costs, risks, and total dependence on farm chemicals. During its evolution, LISA should build and expand on the IPM philosophy. Scientists and farmers will explore ways to reduce inputs and keep outputs and quality high without sacrificing income. The alternatives, however, must be practical, affordable, and adoptable. One objective that IPM and LISA share is to develop techniques that will allow farmers to reduce their costs and maintain their level

Table 1. Field Crop Pest Scouting Trends in Illinois; 1982, 1985, and 1988

	Corn			Soybeans			Alfalfa		
	'82	'85	'88	'82	'85	'88	'82	'85	'88
	percent of crop acres								
Scouted by IPM consultants	3	5	4	4	4	4	<1	<1	2
Scouted by farmer or family members	41	55	50	37	56	57	10	10	23
Total scouted	44	60	54	41	60	61	11	11	25

of profitability. Sustainability also implies protection of our soil and water resources to assure productivity and other benefits for society, such as a high-quality, stable supply of food and water.

IPM in Illinois

The IPM program has centered on the state's major crops: corn, soybeans, wheat, and alfalfa. In field-crop pest scouting, the most visible IPM activity, scouts monitor fields regularly; and control decisions are based on economic thresholds. During 1988, farmers or pest management consultants scouted 54 percent of the corn acreage, 61 percent of the soybean acreage, and 25 percent of the alfalfa acreage (Table 1). By the year 2000, virtually all crop acres will be scouted.

Pest management consulting, including scouts who charge for their services, is a relatively new enterprise in Illinois that began in the public sector. This practice is now being adopted by the private sector. In 1988, about 50 IPM firms employed 70 full-time staff and 250 seasonal employees to serve more than 1,500 Illinois growers.

Weed Control, LISA, and the Changing Landscape

During the past three decades, the availability and use of herbicides in Illinois have increased dramatically. In 1960, soil-applied herbicides, used on an estimated 5 percent of the corn and soybean acres, were applied primarily in a band at a cost of $2 to $5 per acre. In 1988, herbicides were applied to nearly all corn and soybean acres (Table 2). Most of these herbicides were broadcast — combinations and multiple applications being quite common — at a cost of $10 to $25 per acre. Since herbicides have given such dramatic, economical, and convenient weed control, farmers are not likely to stop using them in the near future.

Tillage. Illinois farmers are changing their practices. Chisel plows have gradually replaced many moldboard plows. More producers are interested in further tillage reduction to conserve fossil fuels, soil, water, time, and equipment costs.

It is said that no-till increases costs and requires more herbicides, but this is not necessarily true. Excellent weed control and corn yields higher than 200 bushels per acre have been obtained using little or no tillage for corn after soybeans, with essentially the same herbicides and rates as those for conventional tillage. With no significant benefit from midseason cultivation, a spray-plant-harvest program has very low inputs. If most Illinois farmers adopted this practice, we would take a great stride toward meeting conservation goals for the state while reducing inputs and helping to assure sustainability.

Ridge-till is another practice that can allow reduced herbicide costs by using band applications over the row and cultivating between the rows.

Rotations. University of Illinois research confirms that farmers moving toward *reduced tillage* rotations are on the right track. Illinois farmers have rotated crops for years, often simply by alternating corn and soybeans. Perhaps without realizing it, they have also rotated herbicides, using different ones for corn and soybeans, thus helping prevent resistant weed species from developing.

Cover crops. Scientists are exploring opportunities to take advantage of the mulching and allelopathic effects of cover crops for weed control. (Allelopathy is the process by which one plant releases chemicals or phytotoxins that inhibit the growth or development of another plant

Table 2. Illinois Corn and Soybeans Treated with Herbicides and Insecticides, 1969 to 1988

	Corn			Soybeans	
	Soil Insecticides	Post-emergence Insecticides	Herbicides	Post-emergence Insecticides	Herbicides
	percent				
'69	70	2	84	1	70
'72	60	3	86	6	83
'76	56	2	95	4	96
'78	65	7	98	1	98
'82	53	1	99	5	99
'85	42	6	99	1	97
'88	32	6	97	45*	96

* Severe outbreak of twospotted spider mites during drought.

growing nearby.) Because more farmers are realizing the folly of letting weeds multiply on set-aside acres, they are using clover or alfalfa as cover crops.

With modest use of herbicides, well-established cover crops such as alfalfa or clover can provide excellent weed control and lower inputs. Inputs are also reduced for no-till corn in legume sod used for set-aside or hay or pasture. A combination of 2,4-D and Banvel can provide early control of alfalfa at low cost. Triazines can control shallow-rooted clover without increasing rates or costs. Taking advantage of the nitrogen from legumes can also reduce inputs.

IPM, LISA, and Plant Pathology

Plant pathologists have long relied upon IPM and LISA. Most disease control programs are based on crop rotation, tillage, and proper planting time. Pesticide applications are primarily restricted to areas where severe disease outbreaks are damaging crops or to protecting high-value crops from pathogens.

IPM is a complementary component of low-input systems, particularly for disease management strategies. Scouting assesses plant disease problems, permitting a more judicious use of inputs that can affect not only the agroecosystem but also the producer's economic returns. Without relying on pesticides, producers can minimize the impact of pathogens by careful selection of seed sources, plant varieties, and tillage and rotation systems based upon scouting and monitoring.

Plant pathology has a history of using low inputs as primary disease control measures. Developing disease-resistant hybrids and cultivars has provided producers with a nonpolluting tool for reducing losses to common plant pathogens, such as leaf blights, root rots, fruit spots, stem diseases, and other destructive problems, at virtually no cost. Crop rotation is another tool that fits into both IPM and LISA as a powerful means to reduce the survival rate of plant pathogens. Nematode, bacterial, fungal, and viral populations all are reduced when suitable host crops are not present. Often, a single season of rotation between crops such as corn and soybeans will reduce pathogens below an economically damaging level. Because both crops fit well into most farming systems in Illinois, rotations are an excellent way to use a pest reduction component that adds very little to the cost of production inputs and offers a superior method of sustaining agricultural production when compared to a continuous crop with the added risks from pests.

Pathogen populations are also affected by other techniques, such as

- *Avoiding pathogens by excluding them from a geographic area:* programs that certify disease-free seed or monitor the movement of plant materials.
- *Eradicating pathogens through scouting and destruction of infected materials:* tillage programs that favor rapid decomposition of plant residues.
- *Protecting plants by modifying the growing environment to favor plant*

↑ John Sawyer checks corn plants at the Brownstown Agronomy Research Center.

↓ Mike Mainz uses a trap to determine insect populations at the Northwestern Illinois Agricultural Research and Demonstration Center, Monmouth.

growth, not pathogen development: row spacing, balanced fertility, and proper planting time.

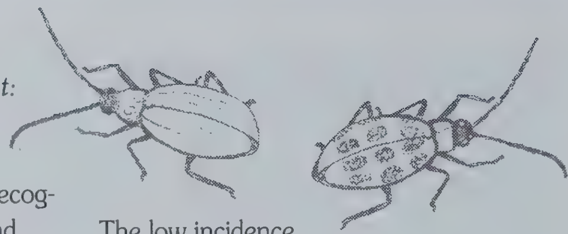
These techniques depend upon recognizing the presence of pathogens and using long-term approaches rather than applying high-input or expensive, short-term measures.

Insect Pest Management in Corn

Effect of rotation. Corn and soybean agroecosystems are susceptible to large fluctuations in insect populations because they contain far less plant and animal diversity than a natural ecosystem. Attempts to manage pests with insecticides in these unstable environments can sometimes produce side effects. An IPM approach reduces insect pests to noneconomic levels without the side effects.

A corn-soybean-corn-soybean rotation, simple as it may seem, is tremendously effective in preventing corn rootworm damage to corn. In Illinois, about two-thirds of all corn is grown in rotation with soybeans (Table 3).

Surveys of 890 fields in 30 counties in the northern half of Illinois from 1986 to 1988 indicated the probability of economic damage from rootworms in corn after soybeans was about 1 in 90 fields (Table 4). Recognizing that crop rotation can prevent rootworm damage, Illinois farmers treated only 13 to 14 percent of the corn following soybeans with a soil insecticide in 1985 and 1988 (Table 3).



The low incidence of rootworm damage in corn after soybeans has permitted farmers to use scouting and rescue treatments for sporadic cutworm pests rather than always applying a soil insecticide. In general, the yield benefits from using a soil insecticide in corn after soybeans are negligible (Table 5); and by not using a soil insecticide, growers saved $10 to $14 per acre and avoided potential adverse environmental effects.

Table 4. A Survey of Corn Rootworm Damage in Corn after Soybeans, Illinois, 1986 to 1988*

Region	Number of fields with economic damage
Northwest	0 in 140
Northeast	3 in 210
West	0 in 120
Central	4 in 210
West	4 in 210
Total	11 in 890

* Surveys were conducted in 30 counties each year, 1986–1988.

Fields with economic damage on average have plants with several roots eaten to within $1^1/_2$ inches of the stem.

Table 3. Cropping Sequences on Illinois Farms, 1985 and 1988

Rotation	Total acres 1985	Total acres 1988	Acres treated with soil insecticides 1985	Acres treated with soil insecticides 1988
	percent			
Corn after corn	34	26	97	83
Corn after beans	60	66	13	14
Corn after other crops	6	8	3	10

Black cutworm vigil. The moths migrate into Illinois in the spring on storm fronts from the Gulf Coast states, making it hard to predict where moths will lay eggs. Because black cutworms have the potential to cause serious problems each year in Illinois, more than 200 cooperating farmers throughout the state monitor the use of cutworm pheromone traps. (Pheromones are chemical substances released by insects to attract others of the same species. Some pheromones are chemically produced for use in insect traps.) By monitoring the traps, one can assess the abundance of cutworm moths, predict when cutting will start, and target the regions in Illinois where scouting is most needed.

This wait-and-watch approach, which has operated for nine years in Illinois, illustrates how IPM has reduced the use of soil insecticides on corn in Illinois from 70 percent of the acres treated in 1969 to only 32 percent in 1988 (Table 2).

Donald E. Kuhlman, program leader for environmental issues; Ellery L. Knake, professor of weed science; Michael E. Gray, assistant professor of agricultural entomology; and H. Walker Kirby, associate professor of plant pathology

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Table 5. Effect of Soil Insecticides on Yields in Fields of Corn after Soybeans, 1982*

Soil insecticide	Average yield, No. 2 corn
	bushels per acre
Amaze 20G	165
Dyfonate 20G	164
Furadan 15G	168
Lorsban 15G	166
Untreated	167

* Average of seven fields in Champaign, Christian, Lee, Morgan, Ogle, Piatt, and Sangamon counties.

Conservation Tillage and Sustainable Agriculture

John C. Siemens

Can conservation tillage and sustainable agriculture be compatible? It has been speculated that adoption of conservation tillage will lead to large increases in pesticide use. A primary objective of sustainable agriculture, however, is to reduce on-farm inputs including the use of herbicides for weed control.

Conservation tillage may be defined as any tillage system that leaves at least 30 percent of the soil surface covered with plant residue after planting. This residue can very effectively reduce soil erosion.

Adhering to this definition, conservation tillage will vary with the previous crop. After corn, tillage operations may include chisel plowing or disking, followed by a limited amount of spring tillage for seedbed preparation and incorporation of herbicides, or no-till could be used.

After soybeans, conservation tillage usually means no-till. Almost any tillage operation used would cover too high a percentage of soybean residue to be called conservation tillage.

Reduced soil erosion. Conservation tillage systems have been developed primarily to reduce soil erosion. Modern herbicides have facilitated the development and adoption of conservation tillage, resulting in speculation that widespread adoption of conservation tillage would increase pesticide use. Although pest problems are sometimes different and pesticide use patterns often change, adoption of conservation tillage has not led to large increases in pesticide use.

Because conservation tillage significantly reduces soil erosion and water runoff, it ensues that conservation tillage can also reduce contamination of surface water and areas adjacent to treated fields by reducing runoff of pesticides absorbed by sediment and dissolved in runoff water. Thus, the net effect of adopting conservation tillage should be fewer contamination problems.

↑ Ridge-till planted corn after cultivation.

Although no-till depends on herbicides for weed control, it allows farmers to reduce significantly their machinery inventory and use (reduced on-farm inputs). Ridge-till, however, may be the conservation tillage system least dependent on herbicides.

Ridge-tilling. A ridge-till system has many advantages. Weeds in the row are controlled at planting by a sweep attachment on the planter. Weeds between the rows are controlled by timely cultivation. With early planting, herbicide use is limited to application of a 12- to 14-inch band over the row. A broadcast herbicide application may be necessary if weeds emerge before planting. Other advantageous features are low machinery requirements and costs, generally good crop yields, and thus excellent profit potential.

A major disadvantage of ridge-till is that the system is somewhat limited to row crops. Small grains, narrow row soybeans, and forages do not fit well into this system, because it is impossible to form ridges in the narrow rows in which they are planted.

Sustainable agriculture promotes livestock grazing and crop rotations other than just corn and soybeans to minimize the need for off-farm inputs. Widespread integration of forages, wheat, oats, and livestock with the main crops of corn and soybeans would be a major change.

Soil erosion could be significantly reduced, especially if the soybean acreage were reduced. Production of winter wheat or alfalfa results in much less erosion than do corn or soybeans. Winter wheat and forages are commonly grown with less herbicides than row crops. Overall herbicide use could be decreased substantially with more crops, crop rotations, and livestock. However, it will be difficult to reduce both tillage and herbicide use, especially with continuous row cropping.

John C. Siemens, professor of agricultural engineering

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Humans with health-conscious spouses are not the only ones who may be surprised to see high-fiber supplements added to their diets. If processing costs can be kept down, more high-fiber feedstuffs may find their way into the diets of livestock as well.

Improving High-Fiber Diets of Livestock

George C. Fahey, Jr.

Very large amounts of crop residues and other high-fiber feedstuffs with a low nutritive value are available on an annual basis. One rather conservative estimate is that the total farm crop residue supply in the United States is 500 million tons per year. Eighty percent of that total is corn stover, wheat straw, and soybean residue — materials common to Illinois.

Processing required. Processing usually is necessary to release the energy trapped in crop residues. Treatment, however, should not cost more than the value of the endproduct. Processed feeds should be more acceptable to the animal, resulting in improved feed intake. Processed feeds should be digestible at a higher rate, to a greater extent, or both, and thus improve nutrient availability.

Finally, it is important that the animal producer recognize that manipulating the usual protein and energy supplementation regimen may be necessary to achieve an economic return on the processing investment.

Chemical treatment is one method of upgrading fiber quality. Chemicals available for use include hydrolytic agents (hydroxides, ammonia, and urea), oxidizing agents (ozone, chlorite, sulfur dioxide, and hydrogen peroxide), and chemical mixtures (hydroxides and alkaline hydrogen peroxide).

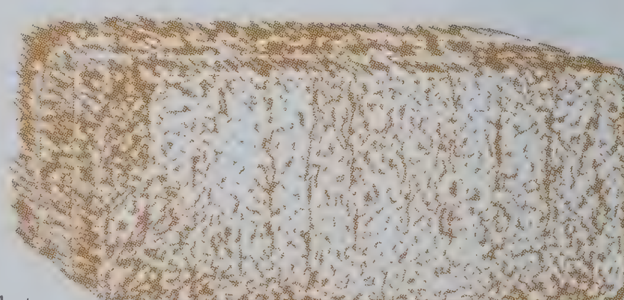
Hydrolytic agents hydrolyze certain chemical linkages in the plant cell wall; they also swell and disrupt fiber structure. Oxidants partially degrade lignin, a normal plant constituent and perhaps the most refractory natural organic compound in nature. A chemical mixture of a hydrolytic agent and an oxidant could provide the most efficacious chemical treatment possible.

The right stuff. When we began testing alkaline hydrogen peroxide, we sprayed a mixture of 5 percent sodium hydroxide and 2 percent hydrogen peroxide on low-quality fibrous feedstuffs. Results indicated that the treatment is an efficacious means of markedly improving the nutritive value of low-quality crop residues — in this case, wheat straw.

- Sheep, growing steers, and finishing steers showed significant weight gains. The livestock were able to digest between 65 and 70 percent of the diet organic matter and diet fiber.
- Dairy cows in early lactation that were fed diets of 12.5 to 37.5 percent treated wheat straw digested 66 percent of diet organic matter and 53 percent of diet neutral detergent fiber. These cows produced 31 kilograms of milk per day (27 kilograms per day of fat-corrected milk).
- When these same dairy cows in midlactation were fed diets of 20 to 60 percent treated wheat straw, they digested 68 percent of diet organic matter and 57 percent of diet neutral detergent fiber. Milk production was 25 kilograms of milk per day (24 kilograms per day of fat-corrected milk).

Recent research on oat hulls indicates a somewhat more favorable response than was noted with wheat straw. Laboratory screening of many low-quality fibrous feedstuffs also indicates that this treatment is effective in improving the feedstuffs' nutritive value.

George C. Fahey, Jr., professor of animal sciences



The Role of Ruminant Animals and Forages

Dan B. Faulkner and Don W. Graffis

In referring to a sustainable agriculture, "sustainable" implies a system that can function perpetually. If we can hope to create this kind of system, we must preserve and conserve the basic resources — soil, water, and air.

Water quality is an increasingly sensitive topic, particularly in reference to chemical contamination of drinking water. Land used for hay and pasture has a lower potential for contamination of surface water and groundwater than does land used for crops. Acre by acre, water runoff for hay and pasture is less than runoff from row crops. Water runoff from hay and pasture also is cleaner, containing less soil sediment and lower levels of fertility nutrients and pesticides. Hay and pasture fields filter the runoff water, keeping a greater percentage of water contaminants in the field.

Lower Chemical Inputs

Hay and pasture fields require lower levels of pesticides than do row crops. Although herbicides may be used to establish perennial hay and pasture fields, this occurs no more frequently than once every four years. Herbicides may be used to maintain hay and pastures as weed populations begin to take over or present a health hazard to livestock. Because these applications are rarely over the entire acreage, the total amount of herbicide normally used is small. Insecticides are used for hay production and for some of the most productive pastures. The total amount of insecticide applied per pasture acre is less than for hay, however, and both herbicide and insecticide applications are less than for corn.

Hay and pasture fields are fertilized at lower levels than row crops. Even on the more productive grass pastures, nitrogen (N) is rarely used at a rate above 150 pounds per acre. Although water runoff from hay and pasture fields may carry nitrogen, less nitrogen is lost than from row crops because of the filtering action of hay and pasture plants and the lower net amount available.

The Beef Advantage

Appropriate use of forages and manure can reduce input costs and soil erosion on many farms. Beef cattle fit into these systems because of their unique ability to use forages and prosper with minimal management inputs. Other ruminant animals may use forages, but they require more management. When forage is a limiting factor, weight gains will be reduced unless harvested or purchased feeds are fed. Profitable year-round systems of beef production not only maximize forage use by the grazing animal, but also minimize fertilization, grain feeding, and the use of purchased supplemental feeds. These systems reduce farm expenses and limit the use of hydrocarbon-based fuels for nitrogen fertilization and harvesting, which can supply farm enterprises with alternatives that are economically profitable, environmentally sound, and biologically efficient.

The integration of ruminants onto farms in the Midwest may improve productivity and profitability. Animal production is an excellent example of a value-added enterprise, because livestock and crop production can be mutually supportive. The challenge is to integrate economical production systems with available forage resources. In such systems, the ruminants can graze forages and recycle nutrients through the decomposition of manure. Rotational grazing of grass-legume pastures, sequential grazing of cool-season and warm-season grasses, and supplemental feeding of ruminants grazing crop residues can be used to control animal movement to further enhance the fertility contribution of manure.

These systems should also have a positive impact on soil productivity and water quality. As concern about the environment increases among farmers and the general public, interest grows about potential sources of surface water and groundwater contamination from agriculture. Cultivated row crop and pasture fields are potential sources of concern. Pasture management practices increasingly depend upon the use of agricultural chemicals, specifically nitrogen fertilizer. For agricultural production and water quality to coexist, it becomes more critical to evaluate sustainable management programs that minimize surface water and groundwater contamination.

Much of the land in the Midwest is subject to erosion, but appropriate rotation, tillage, and management practices can reduce erosion. The crop residues can be an economical feed resource, particularly if they are grazed and if some residue is left in the field to control soil

→ Cattle at the Dixon Springs Agricultural Center.

↓ Switchgrass at the Dixon Springs Agricultural Center.

erosion. For the farms that have some land unsuitable for row-crop production, sod-forming grasses and legumes can effectively control erosion.

Cool-Season Grasses

Cool-season grasses (for example, tall fescue, smooth bromegrass, orchardgrass, and Kentucky bluegrass) make most of their growth in the spring and autumn. This growth pattern often leads to a deficiency of summer pasture for ruminants. Split applications of nitrogen fertilizer can improve the yield distribution of cool-season grasses, but labor costs and the threat of water contamination may increase.

Because fescue is the predominant cool-season grass in Illinois, this midsummer problem is intensified. Much of this fescue is infected with an endophytic fungus (*Acremonium coeniphialum*) that reduces animal performance, particularly during the hot midsummer period. This fungus has been shown to reduce stocker cattle gains about 50 grams per day for each 10-percent increase in infection. Conception rate is also reduced when cows graze heavily infected tall fescue. Changing management practices such as the calving season can alleviate much of this problem. When seeded in pastures of infected tall fescue, legumes are particularly effective in reducing the toxic effects of the tall fescue endophyte.

Legumes Play Many Roles

Legumes are also important in forage systems as a source of nitrogen for cool-season grasses, improved forage yield during midsummer, and high-quality nutrients for the animal. Legumes grown with cool-season grasses can improve the pasture's summer productivity as well as eliminate the need for nitrogen fertilizer. Legumes can be added to grass pastures with no-till seeding systems to meet the nitrogen needs of the associated grass and improve the feed nutrient value of the pasture for the grazing animal.

Legumes produce nitrogen symbiotically with the proper Rhizobium bacteria. This symbiotically produced nitrogen presents little risk of contaminating surface water or groundwater. The nitrogen is produced, stored, and released from nodules on the legume root. Because the release rate is relatively slow, associated grasses or the legume plants themselves use the released nitrogen for growth.

Legumes reduce the dependency on petroleum-derived nitrogen but may require pesticides and additional lime, phosphate, potash, and other minerals to maintain high productivity. A substantial energy savings could result, however, because about 33 percent of the energy used in U.S. agriculture today is for nitrogen fertilizer.

Research at Illinois has shown that adding alfalfa can increase the rate, extent, and overall digestibility of the diet for ruminants. Legumes have higher concentrations of crude protein, total nonstructural carbohydrates, and digestible dry matter with lower concentrations of cell-wall constituents (fiber) compared to grasses. Therefore, legumes can effectively supplement forages of lower quality when added to the diet at the rate of 15 to 30 percent.

Legumes can effectively improve animal performance when grazed and persist well when used in a rotational grazing system. Sequential grazing demonstrations on southern Illinois farms have shown animal gain per acre that would give similar returns to row crops, based on commercial grazing costs.

Warm-season grasses such as big bluestem (*Andropogan geradii* Vitman) and switchgrass (*Panicum virgatum* L.) produce most of their growth in the summer and provide an alternative forage system for midsummer. The different growth patterns of cool-season and warm-season grasses permit a complementary pasture system to be developed. Furthermore, warm-season perennial grasses require little nitrogen for high yields. We have evaluated warm-season grazing systems for the past four years and found that more cattle can be grazed than on cool-season grasses alone, but animal performance decreases slightly.

It is important to minimize the use of harvested forages in beef systems. Forage harvesting methods are energy-intensive and use of stored forages may result in 40 percent waste during harvest, storage, and feeding. Reducing the amount of harvested forage fed to beef cattle may be possible if the forage is accumulated, winter cover crops are grown, or crop residues are used for grazing in late fall or winter. It would be most efficient to use harvested forages only when necessary due to snow cover or lack of pasture.

Although grazing is the most economical part of the beef system, it cannot be used without an economical way of wintering ruminants. The total system must be considered as one begins to apply available technology to produce livestock economically. Producers need economical forage-based systems to improve productivity and water quality.

During the past decade, studies worldwide have clearly shown that nitrates and some pesticides are being delivered to groundwater from routine agricultural practices. Regionally, in response to hydrologic settings, nitrates in groundwater have increased in a direct, linear fashion, paralleling the increased use of nitrogen fertilizers. Many studies show a direct relationship between the nitrate concentration in groundwater and nitrogen fertilizer rates. Deterioration in surface water quality has also been linked to applying nitrogen fertilizer on pastureland.

Our goal is to combine crop residues, winter cover crops, and forage resources into economical, environmentally sound production systems. Work in this area will continue at the Dixon Springs Agricultural Center and will be initiated soon at the Orr Agricultural Research and Demonstration Center.

Dan B. Faulkner, assistant professor of animal sciences, and Don W. Graffis, professor of forage crops, Department of Agronomy

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Producing Fuel from Wastes and Other Biomass

Donald L. Day and John R. North

As world oil resources dwindle or become interrupted, interest increases in alternative energy resources. Livestock wastes, crop residues, and other sources of biomass are potential sources of renewable fuels, both liquid and gaseous.

Liquid fuels (ethanol, butenol, and vegetable oils) have a highly concentrated energy content and are suitable for mobile uses. Gaseous fuels (methane and hydrogen) are less concentrated and better suited for stationary uses, although they can be compressed or even liquified, at considerable expense, for mobile uses.

One University of Illinois project examines the feasibility for an integrated biomass energy system for an Illinois farm. Funded in part by a grant from the Illinois Department of Energy and Natural Resources, the project is part of the work at the University's Swine Research Center, which has a capacity equivalent to a farrow-to-finish unit marketing 3,000 hogs per year.

This totally enclosed, modern confinement unit has partially slotted floors. The manure produced from some of the buildings is scraped from under the slats several times per day to a central sump and pumped to an anaerobic digester to produce biogas that is about 60 percent methane, as compared to the almost 100 percent methane in natural gas.

The tank of the digester consists of four compartments: the main reactor, sludge storage, gas processing, and gas storage. Incoming manure is mixed and preheated in a separate tank (Figure 1). The digester is insulated with polyurethane and sealed with a spray-on rubber lining. The part of the tank that is not buried is mounded over with earth for additional insulation. Because the tank is too large to transport, it was built on site.

Biogas produced is being used in an engine-generator that consists of a 300-cubic-inch, six-cylinder industrial engine coupled to a 25-kilowatt synchronous generator. The engine-generator is controlled by an automatic transfer switch that is activated by either a utility power failure or a programmed time clock. The biogas should provide 250 kilowatt-hours

↑ An overview of the University of Illinois Swine Research Center. The digester is located between the buildings and the lagoon.

of electricity per day, about half the farm's electrical load. The electricity can be used to displace purchased electricity, to reduce peak power demands, and to provide standby power. Although there have been numerous design and operational problems with the digester and the generator, they have operated nearly automatically.

The digester at the Swine Research Center is envisioned as part of an integrated biomass energy system for Illinois agriculture. An intensive interdisciplinary study has shown that energy independence can be achieved by using 10 percent of an Illinois corn crop to produce ethanol liquid fuel needed to power the tractor, combine, and truck used in producing the crop. Figure 2 depicts the energy scheme.

In such an operation, a nearby feedlot uses the wet stillage as a protein supplement and thus avoids expending energy drying the stillage. Manure from the feedlot is the substrate for an anaerobic digester that produces methane as the process fuel for the alcohol plant. The ecological and energy cycle is completed when the sludge from the digester is applied to the cropland, thus furnishing nutrients required for another crop.

This totally integrated system provides an interesting ecological and energy cycle for the farm, while achieving considerable energy independence, using corn reserves, and helping the local economy. All major phases of the project — use ethanol production of stillage in livestock rations, methane production, and conversion of a diesel tractor to run on ethanol — have been researched; but converting the diesel engine is not practical at this time. A better approach uses diesel and ethanol in a dual-fueling mode.

Donald L. Day, professor of agricultural engineering, and John R. North, graduate research assistant

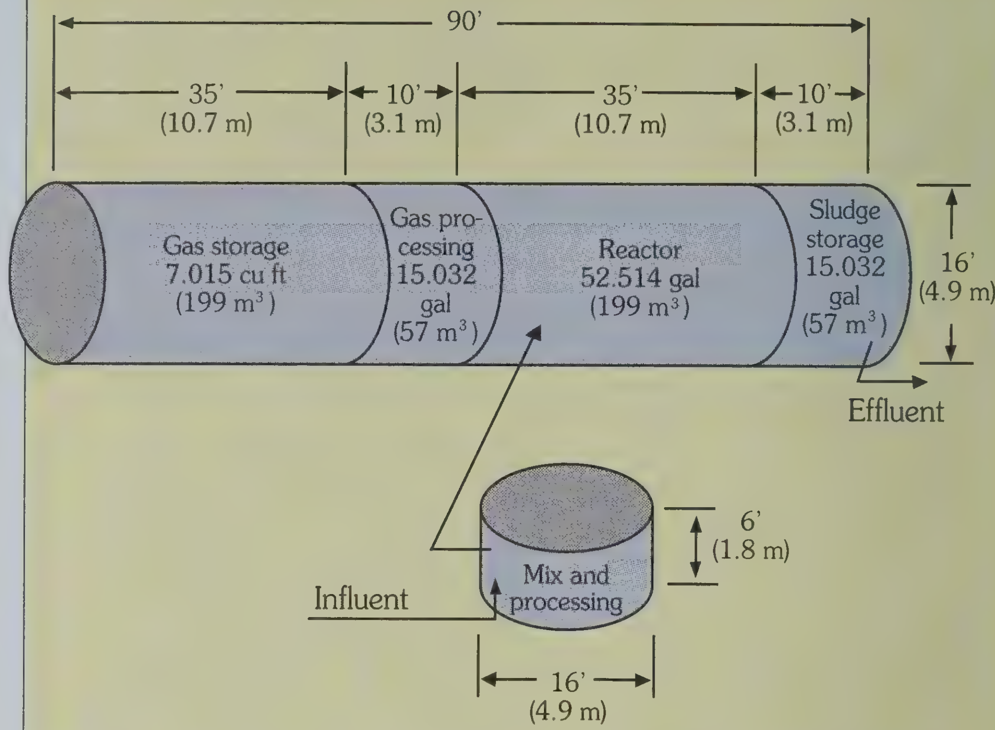

Figure 1. The anaerobic digester at the University of Illinois Swine Research Center was constructed by Energy Resource Systems, Dewey.

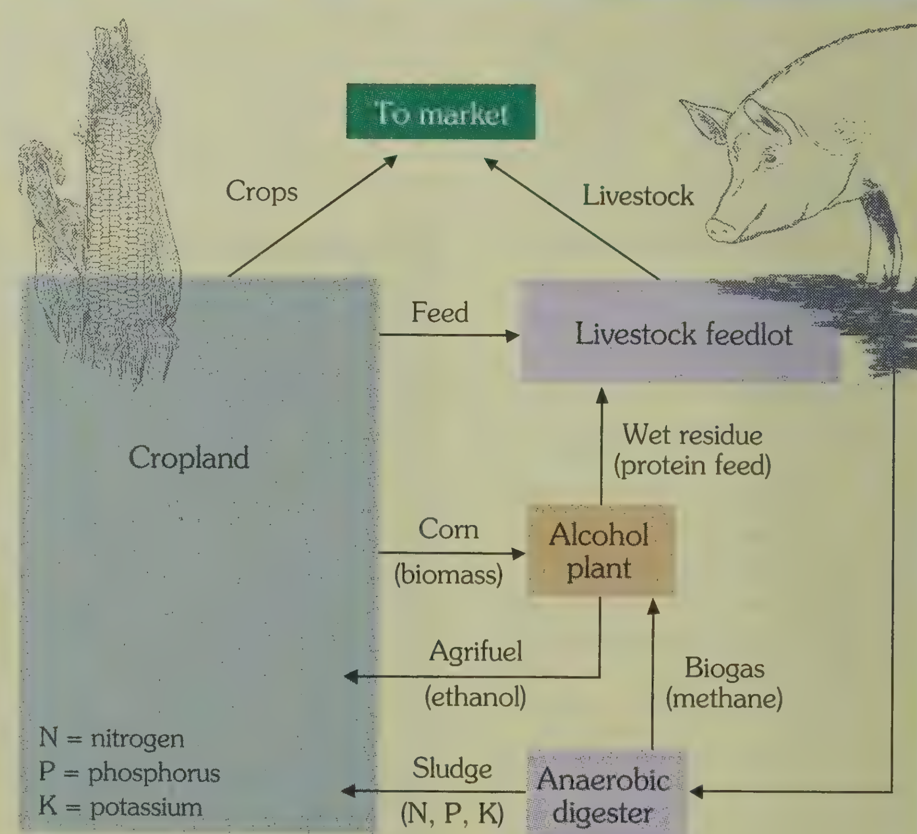

Figure 2. The flow scheme of the proposed integrated farm fuel system.

Grazing Management on Farm Woodlands

Ann Dennis

Habitat for native plant and animal species is scarce in Illinois. Farm woodlands provide much of this habitat, making farm activities that affect the quality of the woodlands a major concern among conservationists. Forest managers and conservationists have long recognized that livestock grazing can be destructive. However, most damage is not an inevitable consequence of grazing but rather the result of inappropriate livestock management practices.

Experience in other parts of the United States indicates that many negative impacts of woodland grazing can be eliminated by adjusting the number and distribution of animals and the time of use. Indications are that we can develop methods so Illinois farmers can simultaneously use woodland resources for livestock production and protect habitat quality. But we will need information on the links between specific grazing practices and specific levels and types of impacts.

Habitat quality problems associated with livestock grazing in woodlands are

- Destruction of understory plants that provide cover and food for wildlife,
- Reduced species diversity and ecological quality of understory plant communities, and
- Increased sediment production from ground bared by trampling.

As a first step in determining how specific livestock management practices may be linked to these problems, I conducted a survey in wooded portions of pastures under different types of cattle-grazing use at the Dixon Springs Agricultural Center in southern Illinois. All sites

↑ Ungrazed woodland.

↑ Woodland heavily used by cattle year-round.

↑ Woodland grazed by cattle in summer and fall only.

were in upland oak-hickory woodlands with overstory trees of similar size and density.

Negative impacts were most pronounced on sites where cattle were held for feeding during winter. These sites receive very heavy use during the winter and moderate use at intervals during the growing season. Shrubs and saplings were virtually eliminated, with native woodland herbs largely replaced by weeds. Bare ground was exposed on as much as 10 percent of the area.

Fewer negative impacts were evident on sites with other use. Woodlands used only after harvest of a hay crop on the adjacent open pasture actually had the greatest development of herb and shrub vegetation. These sites also had the richest understory flora, with a greater number of native woodland species than sites that had been protected from grazing for 15 years. Seedlings of the full range of overstory tree species were abundant on many sites, but saplings — mostly sugar maple and black cherry — were present only on sites protected from grazing.

> "Woodlands used only after harvest of a hay crop on the adjacent open pasture actually had the greatest development of herb and shrub vegetation."

Overall, prospects seem favorable for identifying grazing management practices compatible with most habitat conservation goals. Heavy use in winter and moderate use throughout the growing season both seem to reduce habitat quality. However, dividing pastures to exclude livestock from woodlands until June or July may produce more habitat improvement than completely removing livestock. Further research may pinpoint critical times, use levels, and site characteristics that refine these general observations.

Implementing of grazing management plans aimed at conserving woodland wildlife resources seem to pair naturally with developing of native warm-season grass pastures for forage improvement. Pastures with large wooded areas are the best choice for warm-season pastures. The shade provided by the woodland has most value during the optimum period for use of these forages. This period is also when grazing may least damage the quality of the woodland habitat.

Ann Dennis, visiting assistant professor, Department of Forestry

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↓ Cattle grazing at the Dixon Springs Agricultural Center.

Agroforestry

Timothy D. Marty

The historical relationship between agriculture and forestry has been fairly consistent: agriculture was considered a dominant use and forestry a residual use of the land. Half the state was once forested, but only about 11 percent remains forested today. As concerns arise over agricultural sustainability, realization emerges that trees and forests have an important role to play in rural land use.


Black walnut trees are intercropped with clover.

Agroforestry is a label often applied to a range of activities that integrate forestry and agriculture. Three general categories of activity may fall under the heading in Illinois: utilization of trees on primarily agricultural lands, tree farming, and intercropping of trees and crops. Windbreaks and stream corridors are the two most obvious examples of the first category. Trees used thusly have limited timber value but may provide benefits in terms of soil and water conservation, wildlife habitat, and scenery.

At the other end of the spectrum, tree farming (the intensive cultivation of trees for financial returns) may be considered a different form of agroforestry. Although the timing of costs, returns, and annual cash flow may be problematic in some instances, research indicates that managing lands for timber production can be a profitable long-term investment. Real, after-tax returns to forestry investments range from 4.8 to 14.9 percent. When the benefits available from government incentive programs such as the Conservation Reserve Program are included, the returns become even greater.

A more traditional use of the term "agroforestry" may refer to the intercropping of trees and crops in the same area. Of greatest interest in Illinois and throughout the Midwest is the multicropping of eastern black walnut trees in approximately 40-foot rows with alfalfa, clover, winter wheat, or soybeans grown between the rows. Crop returns help offset establishment costs for the walnut trees and provide annual income. When the walnut trees reach a size that effectively precludes crop production, nut yields begin to provide annual returns. Eventually, the walnut trees are harvested for either sawlogs or veneer. Alternative walnut multicropping regimes provide an annual equivalent value of $30 to $90 per acre. Although these cropping patterns are not widely practiced, there is interest in exploring opportunities for tree and crop intercropping.

More than 1.8 million acres, roughly 45 percent of the forest area of Illinois, are classified as being under farmer ownership. In addition, many thousands of acres of marginal cropland have been identified as suitable for conversion to forestry production. The Illinois Commission on Forestry Development noted, "Trees are a crop that, if properly grown on appropriate sites, can yield a higher long-term net return per acre than other crops." Clearly, the forestry and agricultural communities must explore the substantial opportunities that forestry offers for environmentally sound, sustainable land use.

Timothy D. Marty, assistant professor of forestry

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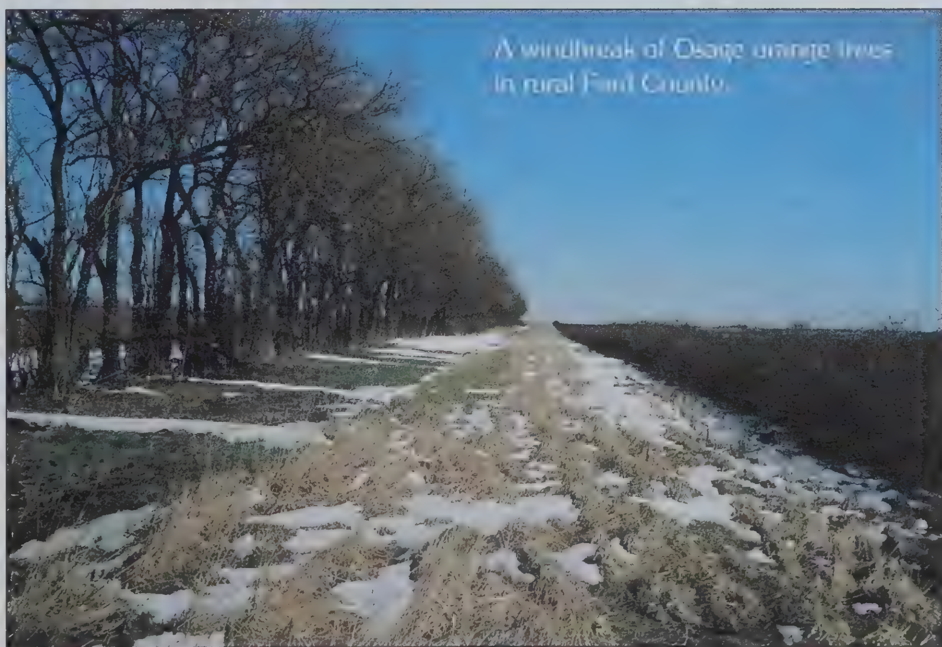
A windbreak of Osage orange trees in rural Ford County.

Donn Klor: One Farmer's Experiences

Tina M. Prow

Farmers are changing the way they think about agriculture. Top yields are no longer the driving force behind every operation — Illinois farmers are increasingly conscious of how investments affect their bottom lines and how agricultural practices affect the environment.

These farmers are striving for a sustainable agriculture, according to Donn Klor, a farmer in Buffalo, Illinois. Klor is past president of the Illinois Sustainable Agriculture Society (ISAS). Founded in 1988, the ISAS is a forum for growers, like Klor, who are concerned about the future of agriculture.

"Many farmers are exploring options for reducing inputs, such as less tillage or fewer chemicals. For some, these changes are strictly driven by economics," he said. "But more often, I'm seeing farmers change their farming practices because they're also concerned about food safety and groundwater quality; about soil erosion; and about leaving good farms for future generations.

"These economic and environmental goals are needed if we are to 'sustain' agriculture into the future."

A Conventional Operation

Klor considers his farm conventional — corn and soybeans, plus a few acres of wheat, oats, and alfalfa. He is open to unconventional ideas about farming, however, and searches for practices that reflect his interest in sustainable agriculture.

Reduced tillage and herbicide trials are among Klor's approaches toward sustainable agriculture. Reduced tillage saves nearly 40 percent on fuel for the operation, a low-input success, said Klor. Ongoing experiments with herbicide application techniques and rates have cut chemical use one-third to one-half, which Klor termed a success from both low-input and environmental standpoints.

Farmers are interested in a sustainable agriculture network to share ideas and successes. Last summer, the ISAS organized a tour of farms where producers are trying some of the sustainable agriculture practices being discussed today.

On display were crops planted into no-till fields; cover crops that add nitrogen to the soil and control erosion; herbicide experiments designed to test the effectiveness of reduced rates and band applications; and a no-till aerator used to break the plowpan without disturbing the soil surface. (The plowplan is the layer of soil just below the plow layer.)

"The ISAS has an interest in anything that can fall within the realm of sustainable or low-input agriculture, the 'low-input' referring to what is not spent to put farm crops in and the 'sustainable' referring to another way of looking at farming with a very definite environmental slant," Klor said.

Use of Chemicals Questioned

When farmers get together to talk about sustainable agriculture practices, he said, the conversation always turns to agricultural chemicals. Farmers seek alternatives to high-cost fertilizers and pesticides that pose risk to human health and the environment. Many farmers are reducing rates of chemicals and choosing those that pose the least risk over those that leach or are known carcinogens.

In addition, many farmers are intrigued by farm trials which show that cover crops appear to reduce the need for fertilizers and herbicides and to improve soil tilth. Although cover crops on his farm have been unsuccessful over the long term, Klor is convinced there is some potential for this centuries-old, "new" management strategy.

Still other farmers are moving away from chemical inputs and toward organic farming. According to Klor, organic farming can be sustainable, and many organic farmers belong to the ISAS; but sustainable agriculture is not exclusively organic farming.

"We embrace it, but we aren't organic. There's a market niche for organic products, but we don't think that the vast majority of the ag community is going to go organic. We see the trend as seeking out systems and products that are more environmentally sound," he said.

One problem he sees with organic farming is that few researchers or farmers understand how a particular system works, making it hard to identify and evaluate specific practices contributing to the success of an organic system.

Still, some organic farms are successful, and farmers are interested.

"If someone across the fence can grow 50 or 60 bushels of beans per acre and 150 to 250 bushels of corn and do it without going to the store to buy inputs, I'm extremely interested.

"I might be able to take part of an organic practice and put it on my farm and get similar results," he said. "It might reduce my costs or change a practice that's not good for the environment. But the information transfer isn't there. You have to seek people out who will show you what they do."

Donn Klor cultivates his field.

Farmers Seek Information

The lack of research and educational programs about organic farming and other practices associated with sustainable agriculture is a complaint of farmers around the state, Klor said. In most cases, farmers hear and read about practices; then they apply those practices on their own farms without direction from university researchers.

"A fellow on the ISAS summer tour said most of his information on cover crops came from the University of Illinois library, from books printed around the turn of the century," he said. "We think it's extremely important that researchers at land-grant and other schools take stock and realize they haven't done much work in cover crops and other alternatives for 40 or 50 years."

Klor said the ISAS considers the federal LISA (low-input sustainable agriculture) initiative one way to get quick answers to farmers' specific questions about cover crops, reducing tillage, adjusting chemical rates, and other practices that might lead to a more sustainable agriculture.

"I don't think LISA will eliminate the broad-based research," he said. "Instead, it can be considered extra money to target a particular project. With this designated research, and with renewed interest in applying our current knowledge and new technologies to some of the old practices, I think we have the ingredients for some fantastic programs."

Besides production research, farmers need research on effects of chemicals upon health and the environment, he said. As members of society, farmers count themselves among those who do not want potentially dangerous chemicals on foods, in the water supply, or harming wildlife. And cancer is increasingly a concern among farm families.

Klor said at least one study shows that a person who uses farm chemicals over 20 days a year is six times more likely to have cancer. "There are tremendous differences among herbicides; some are more dangerous than others, but the farmer often doesn't know the risk.

"We need labels that spell out the hazards so we can make better choices," Klor said.

Klor said health and environmental issues related to agriculture are likely to affect the 1990 and 1995 farm bills. Testifying in Washington for bills and hearings related to agriculture have convinced him that these issues are of prime concern to too many groups to be ignored.

Although he finds this level of interest encouraging, he sees some danger of health scares and overzealous legislation with so many people unfamiliar with agriculture involved in farm policy at the national level.

"Many diverse coalitions are interested in agriculture, and the industry has a lot at stake. But the common threads for all groups appear to be an interest in improving net income for farmers and in reducing environmental risk.

"I think these goals are attainable and that farmers who are part of the sustainable agriculture movement are working toward these goals," he said.

Tina M. Prow, Extension communications specialist, Office of Agricultural Communications and Education

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Sustainable Agriculture: The Industry's View

Tina M. Prow

Although there is some confusion about what sustainable agriculture is and how Illinois farmers will implement it, the economic and environmental goals of this farming concept have drawn support from widely diverse groups and agencies in the state.

"The 'sustainable' part of the concept is all about farming the right way so that there are no problems with the food chain, with health, with groundwater, with keeping the soil in place — there can't be any opposition to that," said Donn Klor, past president of the Illinois Sustainable Agriculture Society (ISAS), a farmers' organization.

"These are things the general public is concerned about, and farmers have to address those concerns," he said.

Deborah Cavanaugh-Grant, resource planner at the Department of Energy and Natural Resources (DENR), worked closely with the ISAS as it developed in 1988, because members were interested in protecting groundwater quality, also a priority of the DENR.

"Sustainable agriculture has many definitions, including 'organic farming,' but it really is whatever people need to do in light of potential environmental problems and maintaining profitability for farmers, farm communities, and society," she said.

There is much to be gained through the sustainable agriculture movement, according to Virginia Scott, president of the Illinois Environmental Council. The Council represents a coalition of more than fifty environmental groups.

"We see the voluntary reduction of agricultural chemicals by using other techniques and technologies to maintain crop production as very positive from the standpoint of protecting water quality, soil quality and conservation, and health of the ag population," she said.

Although reducing chemical use is commonly associated with sustainable agriculture, this movement is not expected to affect sales at ICI Americas, Inc., an agricultural products company.

"I think most farmers are not abusing ag chemicals. They can't afford to pay for chemicals if they don't get a return on their investment," said Barbara Hook, an ICI representative.

Larry Werries, director of the Office of Intergovernmental Affairs and former director of the Illinois Department of Agriculture, agreed that economics motivate most Illinois farmers to use only those inputs necessary for operations. Profit is the key to any further reduction of inputs on a farm, he added.

"If farmers can maintain profitability and use no more outside inputs than those they can come up with right on their own operations, that's good; there is potential for those operations to be more benign to the environment. But without profit, the operation will not be sustained for very long," he said.

One benefit of the sustainable agriculture movement is that it may help make farmers more aware of management practices that pose the least threat to the environment, he said.

He cautioned, however, that more research is needed on many practices advocated for sustainable agriculture. Similarly, Len Gardner, executive director of governmental affairs at the Illinois Farm Bureau, said there is a particular need for research under real-farm, practical conditions and for research on farm management.

"Farmers have generally looked at how they can reduce inputs, and in the past few years we've seen more pest scouting and more reduced tillage," he said. "But, as farmers move away from ag chemicals, they've got to be willing to put in more management time and be better managers.

"It takes top-quality management to reduce the number of trips over a field, or reduce tillage, or scout for pests."

Until there is more research and education on many aspects of sustainable agriculture, it represents added risk on some farms, he said.

Tina M. Prow, Extension communications specialist, Office of Agricultural Communications and Education

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Solar Salt Ponds

Ty A. Newell and Donald L. Day

A one-half-acre salt-gradient solar pond warms the lop-eared boarders at the new Imported Swine Research Laboratory on the campus of the University of Illinois at Urbana-Champaign (UIUC). This new facility uses a technology that borrows concepts derived from studies of various natural lakes that contain salt concentration gradients.

Models in nature. Although the technology is new, as long ago as 1902, the German scientist Kalecsinsky studied the natural solar ponds in Transylvania and suggested building artificial solar ponds to select and store solar energy for home and industrial use.

Natural solar ponds occur where salt deposits (sodium chloride) nearly saturate the lower levels of natural lakes, while the rain and overflow wash the surface, keeping it at low density.

Because salt water is denser than fresh water, normal convection is prevented; solar energy that penetrates the water heats the bottom of the ponds. Because convection cannot occur, which normally would make the water temperature uniform throughout, temperatures as high as 70°C (160°F) have been reached in these natural lakes.

In artificial ponds such as the one providing space heat for the Imported Swine Research Laboratory, the water temperature at the lower levels can rise to 70° to 90°C (160° to 194°F), with the surface temperature remaining close to the ambient air temperature.

Mechanisms. Establishing a salt gradient in the pond prevents convection, so that the salt concentration varies from near zero at the surface to 20 to 25 percent at the bottom of the pond. The presence of the salt gradient results in higher fluid densities at the lower levels of the pond than near the surface, thus preventing the warmer fluid at the lower levels from moving upward.

As shown in Figure 1, a salt-gradient solar pond normally consists of three zones: a thin convective zone at the surface, a nonconvective gradient zone that provides thermal insulation in the middle, and a heat storage zone at the bottom. The pond collects and stores solar energy all year, and the available thermal energy can be extracted via a heat exchanger.

UIUC project. Sponsored in part by the Illinois Department of Energy and Natural Resources, the International Salt Company, and Gundle lining systems, the UIUC project has three objectives.

- To develop and demonstrate a basic but full-scale pond design that can be replicated for various purposes (such as grain drying, space heating, and providing low-temperature industrial process heat).
- To assess accurately the costs of constructing and operating a solar pond in Illinois.
- To monitor pond performance for developing operation guidelines and projecting the economic potential of salt-gradient solar ponds.

Specifications. The project has drawn on technology developed at several research ponds around the country, specifically the one-fourth acre pond at Argonne National Laboratory. The Argonne pond is about 16 feet deep, with sloping sides. The UIUC pond is lined with a high-density polyethylene (HDPE) liner. The liner was manufactured in 22-foot widths and has four to five times fewer seams than other liners, thus less potential for leakage.

Establishing the salt gradient required 2,000 tons of "junk salt," a finely powdered by-product of the crushing and handling processes at salt mines. To prevent the release of salt into the surrounding environment, a one-quarter-acre evaporation system recycles the salt into the pond. Heat exchangers for extracting heat from the ponds are off-the-shelf cupronickel types that have been used successfully at other pond sites.

Productivity. A commercial solar pond of this type would produce heat at a cost of $2.25 per million Btu, compared to $5 for natural gas. Expanded to a full acre, a solar pond could produce thermal energy worth $9,100 per year, providing for cost recovery in nine years. Applicable depreciation and tax credit could reduce the payback time even more.

Ty A. Newell, associate professor of mechanical engineering, and Donald L. Day, professor of agricultural engineering

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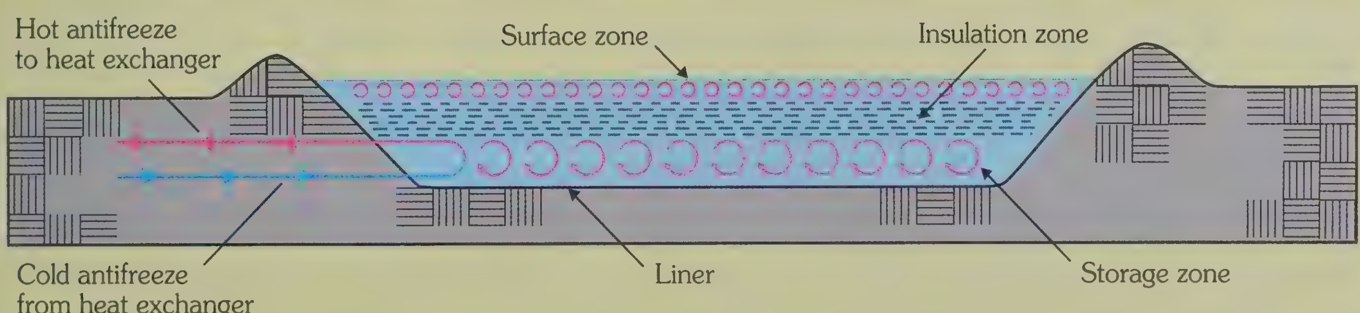

Figure 1. Schematic of salt-gradient solar pond.

Horticultural Alternatives

Schuyler S. Korban

The most concrete evidence supporting the need for low chemical use in agriculture comes from last spring's uproar over the treatment of apples in commercial orchards with Alar — also known as B-9, daminozide, and SADH. The controversy over this one chemical, which enhances red coloration of apples and prolongs fruit hanging on trees, has devastated the U.S. apple industry. Even after the manufacturer halted sales of Alar for food crops and apple growers promised not to use this chemical on the 1989 crop, severe damage has been done and millions of dollars have been lost.

The Environmental Protection Agency is reviewing several chemicals used for fungicide and pesticide control on various horticultural crops. These chemicals are suspected of being hazardous to human health and contributing to air pollution and water contamination.

At the University of Illinois, we have been working for more than 35 years to eliminate the use of chemicals on apples. By introducing genetic resistance into the apple, our goal is to fight off diseases and insects that attack apples.

This work has been quite successful. In collaboration with Purdue and Rutgers universities, the apple breeding program at the University of Illinois has named and released nine newly developed disease-resistant apple cultivars (Table 1). These cultivars can be grown in commercial orchards and the home backyard with 60 to 70 percent fewer chemical spray applications than needed by popular commercial cultivars such as 'Red Delicious', 'Jonathan', or 'Granny Smith'.

This is a significant reduction in the use of chemicals on apples. The new cultivars not only have high quality and attractive appearance, but they can be marketed to the consumer as a "healthful" fruit grown with few chemicals.

Our research efforts include work on developing multiple disease-resistant apple cultivars and also attempting to add insect resistance into our cultivars.

A major direction of the current apple genetics program is to utilize genetic engineering techniques to manipulate the apple. Our goal is to speed up the process of developing disease- and insect-resistant apple cultivars without making major changes in fruit quality and appearance or tree habit and shape.

We are developing cell and tissue culture techniques to regenerate plants from apple leaf tissues and to establish disease-screening techniques for test-tube-grown plants.

We have also conducted basic work at the DNA level. We are now developing techniques to isolate genes involved in disease resistance and establishing ways to transfer these individual genes to apple leaves and then regenerate whole plants that not only carry these specific genes but also express these genes when attacked by a pathogen. In essence, they will "fight off" disease biologically without chemical spraying.

Two new Station bulletins about apples (Bulletins 789 and 790) are available for $1 each from the Office of Agricultural Communications and Education, (217)333-2007.

Schuyler S. Korban, associate professor of plant genetics, Department of Horticulture

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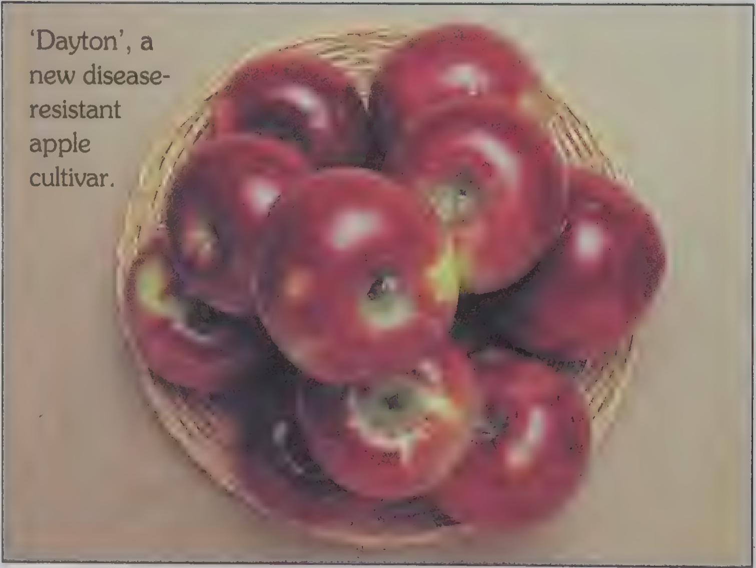

'Dayton', a new disease-resistant apple cultivar.

Table 1. Maturity Date and Color of the Disease-Resistant Apple Cultivars

Cultivar*	Maturity relative to **'Red Delicious'**	Maturity relative to **'Jonathan'**	Fruit color
	- - - - - - - *weeks*	- - - - - - -	
Prima	–4	–3	red
Priscilla	–2	–1	red
Priam	–1.5	–0.5	red
Sir Prize	0	+1	yellow
Redfree	–7	–6	red
Jonafree	–1	0	red
Dayton	–4	–3	red
William's Pride	–7	–6	red
McShay	–3	–2	red

* All cultivars were released in cooperation with Purdue and Rutgers universities; Priam was released in cooperation also with the Institut National de la Recherche Agronomique in France; and McShay was released in cooperation also with Oregon State University.

Sustainable Agriculture at the University of Illinois

Harvey J. Schweitzer

Within recent years, "sustainable agriculture" has become commonplace on the agendas of public policy makers, academics, consumers, environmentalists, agribusinesses leaders, and farmers. Broadly defined, the concept accommodates many interests of people advocating organic farming, regenerative and alternative agriculture, and low-input and resource-efficient farming systems.

Sustainable agriculture has been variously described as a new era in farming and a back-to-basics movement, as a philosophy and a set of specific practices. Embraced by many who are concerned with the environmental impacts of agricultural practices, sustainable agriculture is criticized by others who claim that it promises more than it can deliver in environmental, economic, and social benefits.

At the national level, sustainable agriculture is best known as LISA, low-input sustainable agriculture. Federally funded, LISA is a nationally and regionally administered program of research and education aimed at developing and promoting farming methods that will pose fewer environmental and human health threats, conserve natural resources, and be more sustainable than are practices and technologies now widely used.

LISA's origin lies in the Agricultural Productivity Act passed in 1985 as part of the Food Security Act. Prospects of long-term federal funding are uncertain, but most observers of agricultural public policy agree that environmental and food and water safety concerns will receive major attention in the 1990 farm bill.

Although the federal LISA program is a significant initiative, the most important incentives for action are coming from public concern about the environmental and health impacts of certain agricultural practices. In addition, farmers are trying to reduce their purchased inputs.

UIUC Initiatives

Specific initiatives were taken by the College of Agriculture in 1988 to provide leadership and focus for issues in sustainability. In the Agricultural Experiment Station (AES), a coordinator for research and education programs in sustainable agriculture was named, with support from the Cooperative Extension Service (CES) and the Dean of the College.

An ad hoc committee was named by units in the College of Agriculture, the College of Veterinary Medicine, and the Illinois Natural History Survey. The committee has facilitated the development and submission of proposals to the North Central Region LISA program, initiated an agroecology newsletter and a seminar series, helped local leaders develop a legislative proposal to support on-farm research, developed contacts with agencies and farm organizations, and in general encouraged the development of public education programs, including in-service training for CES staff.

A significant venture stemming from committee discussions is the development of an agroecology curriculum in the College. Efforts are also also under way to link the College's domestic and international programs in sustainable agriculture.

Although some proponents would like to label these developments a "new birth" in the College, others view them as a phase in the evolution of programming in response to societal needs. What is perhaps unique is that the program name provides a focal point for public contact and a more tangible indication of the College's commitment to an environmentally sound, sustainable agriculture.

A Rich Heritage

The College's initiatives in agricultural sustainability and agroecology build upon a rich heritage of both research and education. In fact, the establishment of the Morrow Plots on the Urbana-Champaign campus in 1876 and the initiation of statewide soils surveys in 1902 are often referred to as the beginnings of an unbroken program of research dealing with land resources.

The work of Cyril G. Hopkins at the turn of the century is noteworthy as we reflect on the components of sustainability. A basic concept in his system of permanent soil fertility was farmers as stewards of the soil, with the duty to pass on to their descendants land that is richer than when they took over its management. Hopkins's leadership in establishing facilities around the state for field research emphasized doing research under as near-farm conditions as possible.

The contributions by the Dixon Springs Agricultural Center near Simpson, are impressive, with its emphasis on erosion control, pasture renovation, forage utilization, soil fertility experiments, sheep and

A farm in Kane County.

beef production, and tillage experiments. It was there that George E. McKibben, the "father of zero-tillage," pioneered work that stimulated widespread interest in reducing tillage costs and conserving soil.

Not to be overlooked are the work in farm management, the establishment of the Farm Business Farm Management (FBFM) system to assist farmers in record keeping and management strategies, and the emphasis on farm and home development, followed by rural development and Rural Route assistance programs.

Especially important to the College's recent initiatives are the programs in integrated pest management (IPM). Started in the early 1970s, this systems approach incorporates pest control procedures that result in favorable socioeconomic and environmental consequences. Specifically, the use of alternative strategies in pest management provides a sound foundation for sustainable agriculture programs.

By contrast, much of the College's research may be referred to as "component research," which provides basic information about soils, crops, tillage, fertilization, insect and disease control, and farm management essential to developing sustainable agricultural systems. Data for much of the research span a period of many years and are therefore invaluable sources of information.

↑ Hand application of pesticides using appropriate safety gear at McKibben Plots, Dixon Springs Agricultural Center.

Challenges

The College of Agriculture is in a unique position to lead in agroecology programs and to address problems of agricultural sustainability. As a land-grant institution, the entire University has a mandate to address societal issues. The College has the disciplinary diversity and the expertise to deal with ecological issues relating to farming, the research capability and the educational network to generate and disseminate information, and mechanisms for citizens' input into planning.

A number of challenges must be met if the University and the College are to effectively address agroecological and sustainability issues.

The research base for sustainability must be strengthened.

The research agenda must be flexible. New technologies, such as developments in biotechnology and genetic engineering, and the changing economics of agriculture will alter the nature of problems to be researched.

Greater emphasis must be placed on multidisciplinary research involving several academic disciplines, including those outside the College of Agriculture.

Incremental advances in research and education must be sought. Major breakthroughs may occur, but the emphasis must be on taking significant small steps as opportunities arise.

Funding for applied research must be obtained. Public support for the Leopold Center for Sustainable Agriculture at Iowa State University and the recent $2 million endowment from the Charles Stewart Mott Foundation for Michigan State University programs in sustainable agriculture are but two examples from nearby states.

The research agenda in sustainability must be broad, including studies of alternative agricultural enterprises, new uses for traditional crops, and market development, as well as economic and sociological studies of the impacts of changing technologies, practices, and public policies on agriculture, families, and communities.

Systems must be an emphasis in research. Component research will continue to contribute to better understanding farming systems' complexities.

Research and education on sustainability must be closely linked. On-farm experimentation and demonstration should be a part of the endeavor.

Environmental and ecological concerns and the issue of sustainability in agriculture are high on the agenda for the College of Agriculture. As part of a major research and educational institution, the College has unique strengths and opportunities to make significant contributions to agroecology.

Harvey J. Schweitzer, professor emeritus of agricultural economics and former assistant director, Agricultural Experiment Station

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The Promise of Biotechnology for Sustainable Agriculture

Lila O. Vodkin

Awareness of how agricultural practices affect ecosystems has increased in recent years. The growing interest in protecting the environment and in conserving the productivity of agricultural land coincides with an expansion of knowledge and opportunities in biotechnology — genetic engineering, molecular biology, and recombinant DNA.

We may ask how the advances in biotechnology will affect agricultural practices and products. Basically, genetic engineering is an extension of breeding methods that have been practiced for thousands of years to improve crops and animals. In traditional methods, crosses or sexual matings are made between individuals with desired characteristics, and the offspring are evaluated with respect to certain criteria — such as yield, milk production, and disease resistance.

Gene transfer. The revolutionary change of the last decade is that genes controlling plant and animal traits can now be physically isolated, manipulated, and transferred by other methods. Individual genes can be transferred across species boundaries — for example, from corn to tomato or from bacteria to plants and animals.

Because a complex plant or animal consists of more than 100,000 genes, the transfer of one or a few genes is not going to change the basic qualities of the recipient species. A tomato plant with a corn gene in its makeup is still a tomato; a bacterium containing a human gene is still a bacterium.

Concerns have been raised, however, that these new creations may have negative environmental effects. Caution is necessary, especially in the case of microorganisms that cannot be contained as easily as domesticated plants and animals. Stringent criteria and reviews by local, regional, and national agencies are in place to ensure that bioengineered organisms will not adversely affect the environment. On the contrary, genetic engineering will likely have substantial benefits for less intensive and more productive agricultural practices.

Super plants. One recent development in this area has been the production of viral resistance in tomato plants by transferring a gene from a strain of tobacco mosaic virus directly into the DNA of tomato plants. The viral gene produces a protein necessary for the proper coat structure of the virus.

"Recombinant" tomato plants containing the viral gene express the coat protein continuously but do not show any of the adverse symptoms associated with viral infection. More importantly, the coat protein provides resistance to infection by the virus. In a sense, the virus has been fooled into thinking that the tomato plant is already infected because the plant produces the viral coat protein.

The benefits of engineering resistances to viral, bacterial, fungal, and insect pests will lie in reducing the chemical control needed to maintain healthy, productive plants. In other areas, the use of biological rather than chemical control mechanisms can specifically target a particular pest and reduce reliance on pesticides with a broad spectrum. Chemical control will probably always be necessary to some extent. More futuristic possibilities from biotechnology may lie in producing common soil microorganisms that can detoxify pesticide residues.

The most significant impacts of biotechnology probably cannot be predicted. Many exciting problems of plant and animal development and response to biotic and abiotic stresses in the environment remain to be explored. With few exceptions, the genes that control important agronomic traits such as yield and disease resistance are currently equivalent to "black boxes," their mechanisms unknown. As genetic engineering and biotechnology provide the tools to begin dissecting these complex interactions, unanticipated applications will emerge.

Lila O. Vodkin, associate professor of crop molecular biology, Department of Agronomy

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With few exceptions, the genes that control important agronomic traits such as yield and disease resistance are currently equivalent to "black boxes," their mechanisms unknown.

Agroecology Defined

John M. Gerber

Aristotle wrote that "in natural science it is the composite thing . . . which primarily concerns us, not just the materials of it, which are not found apart from the thing itself." Today Aristotle might have difficulty finding agricultural research on "the composite thing," as science becomes more and more specialized. Yet, to develop sustainable agricultural systems, scientists must think holistically. Some scientists have proposed a new science, agroecology or ecological agriculture, that applies ecological thinking to agricultural systems.

Agroecology is the science devoted to studying agroecosystems, which are complexes of air, water, soil, microorganisms, plants, and animals that humans have modified for agricultural production. An agroecosystem may be a single field, a farm, a community of farms, or an entire region of the country, such as California's Imperial Valley. The goal of agroecology is to understand these complex agricultural ecosystems and to develop technologies to sustain them.

Agroecology uses basic principles of nutrient cycling, predator-prey relationships, and species competition and cooperation to provide a better understanding of agricultural systems. Some properties of an agroecosystem that are useful for scientific measurement are productivity, stability, sustainability, and equitability. When these measures are used to describe an agroecosystem, they are defined in terms of desired socioeconomic outcomes — that is, they have social value. Agroecosystems may be judged according to the goods and services produced, their contribution to human needs or happiness, and their relative distribution among the human population.

For example, the traditional criterion for evaluating an agricultural system's success is productivity. Irrigation is generally considered a social good because it improves productivity. Irrigation also improves a system's stability because farmers no longer depend on unreliable rainfall. But the system is sustainable only if it does not cause environmental problems such as increased soil salinity, erosion, or water shortages. Further, equitability may suffer because not all producers have access to a source of irrigation water. Agroecology attempts to use these properties and others to conceptualize complete agricultural systems.

Expanding on the ecological studies of conservationist Aldo Leopold, some scientists are embracing a revitalized land ethic. This approach allows humans to perceive value in self-sustained agricultural systems that are less resource intensive and that enhance environmental quality and human wellness.

John M. Gerber, assistant director, Agricultural Experiment Station

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↓ Irrigation may improve short-term productivity while decreasing long-term sustainability.

In Progress

College of Agriculture Student Survey

Sustainable agriculture is not a top priority for today's college students, according to a recent survey of 250 first-year agriculture students. The survey indicates that the students need more information on organic and sustainable agriculture than they have upon entering college.

Of six issues facing agriculture today, the students ranked organic and sustainable agriculture as the least important. Their top four priorities were decreasing pesticide use, increasing profitability, reducing soil erosion, and maintaining family farms.

Sustainable and organic agriculture were the two issues about which the students felt least knowledgeable. Slightly more than one-quarter of the 250 students in the introductory agricultural survey course indicated that they had insufficient knowledge to rank either issue.

Although students from rural backgrounds were slightly more likely to rank organic or sustainable agriculture higher than students from urban backgrounds, rural students were four times more likely to feel that they had sufficient information to rank issues related to pesticide use, soil erosion, profitability, and family farms. Slightly more than one-fifth of the rural students and nearly one-third of the urban students indicated insufficient knowledge to rank either organic or sustainable agriculture.

Urban students were less likely than rural students to rank any of the issues, but they were two to three times more likely not to rank sustainable or organic agriculture.

The survey was sponsored by the University of Illinois's College of Agriculture Office of Resident Instruction and the Ad Hoc Committee on Sustainable Agriculture. For further information, call Ann Reisner, (217)333-4787, or Gerry Walter, (217)333-9429, assistant professors, Agricultural Communications and Education.

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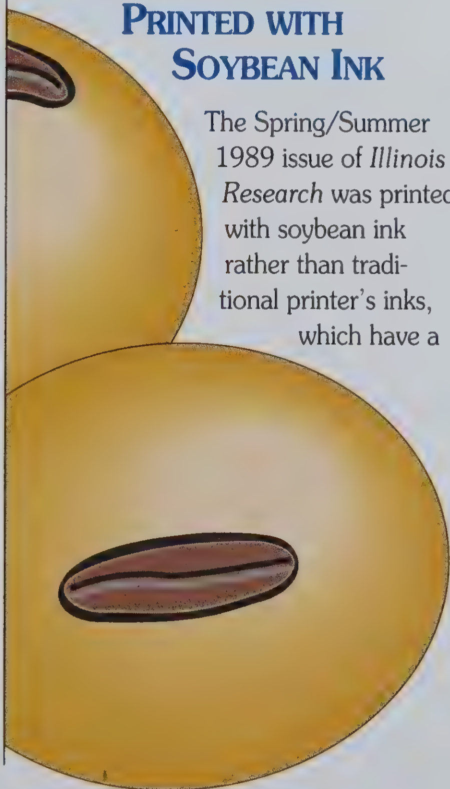

The Spring/Summer 1989 issue of *Illinois Research* was printed with soybean ink rather than traditional printer's inks, which have a petroleum base. Petroleum-based inks contain 25 to 50 percent volatile organic compounds (VOCs) that evaporate and leave a smell. Soybean ink contains less than 3 percent VOCs and has no smell. Soybean ink also produces sharper images and brighter colors than traditional inks.

Because petroleum costs have risen again recently, soybean ink has become an economical, as well as safer and renewable, alternative for printers. We hope to use soybean ink whenever possible for future issues.

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First Open House, a Success Story

An enthusiastic crowd of 12,000 people came to the first annual University of Illinois College of Agriculture Open House. Visitors on March 2 and 3 quickly learned that the College focuses on a lot more than just farming.

A bigger and even better Open House is already being planned for next year. Circle March 1 and 2, 1991, on your calendar!

At the 1990 Open House, faculty and students welcomed visitors at the Stock Pavilion, event headquarters. A brief slide show featured the 125 demonstrations, displays, and lectures that were taking place in nine buildings on the south campus.

Visitors saw research projects that they had read about: machine robotics, biodegradable plastics, and the College's

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famous Chinese pigs. Visitors sampled popcorn, soy-based cookies, and cholesterol-free milk. They learned about acid rain, agroecology, world markets opening in Indo-China and Eastern Europe, Lyme disease, artificial intelligence applications, tissue culture propagation, global warming, and the Egyptian mummy project. They watched a dog training demonstration or toured an automated dairy, the new greenhouse complex, and the Meat Science Laboratory. They attended minicourses on gardening and flower arranging or took a computerized nutrition quiz. Fashions from the 50s were on display. Lunch was even available at "Hotel Bevier" with the Restaurant Management Program.
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New Agroecology Series

The Agroecology Program Papers are available to encourage dialogue about the economic, social, and environmental impact of production agriculture. The papers, which do not undergo formal peer review, report the viewpoint of the author, not necessarily the views and policies of the University of Illinois College of Agriculture or the Agroecology Program.

The postage and handling charge is $2 per paper, payable in advance to the University of Illinois. Copies are free to University of Illinois faculty and staff. For more information or to order papers, contact John M. Gerber, Assistant Director, Agricultural Experiment Station, University of Illinois, 1103 West Dorner Drive, Urbana, Illinois 61801, (217)333-1969.
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Illinois Research

Spring/Summer 1990

Illinois Research

Agricultural Experiment Station
Spring/Summer 1990

Value Added in the Home

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 32, Numbers 1/2

The Cover

A page from the family album reminds us of a simpler time.

These photos are from the archives of the Office of Agricultural Communications and Education.

"At a time unlike any in the past, we must envision the future."

Illinois Research

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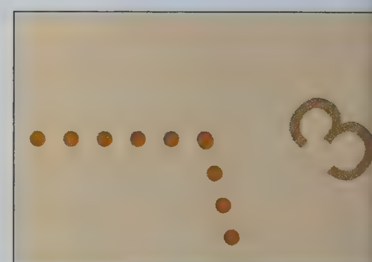

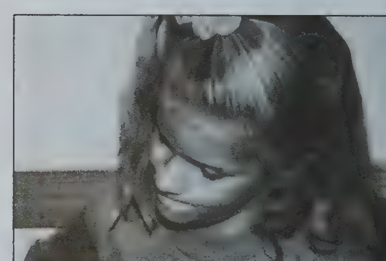

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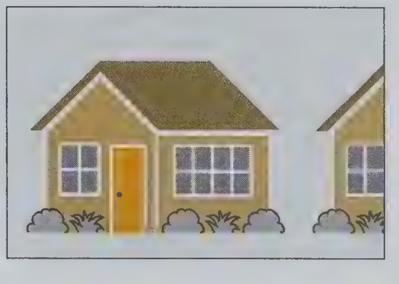
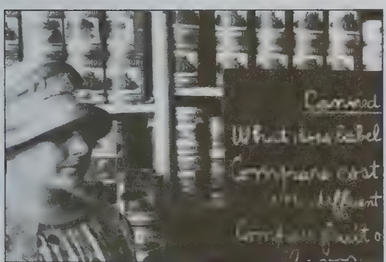




Managing Life's Basics

Donald A. Holt

Within the last five years, two academics who are also mothers and homemakers told me that they could think of nothing within the home economics subject matter that deserved research attention or that should be taught beyond the high school level. Surprised by their opinions, I asked if they really believed we knew everything about foods, nutrition, family relationships, child development, textiles, apparel, interior design, and family and consumer economics. Their answers made me realize how much about home economics we take for granted.

Because of their own relative affluence, advanced education, and ready access to information, the two women and their families regularly bought and used some very sophisticated technology and information. Much of the technology inherent in the products and systems that the women used was invisible to them. They also acquired information from the mass media. Apparently though, they were unaware that important technology and information used routinely in homes were developed, evaluated, and refined within home economics research and educational programs and by private-sector scientists and managers trained in home economics research and education programs.

These women had professional management responsibilities. But they obviously did not equate managing home resources and activities with managing the production activities of a business or managing the service activities of a service institution. They agreed that the management of resources and value-added activities in many homes is poor, but they attributed this to the natural human condition rather than inadequacies in technology or information available to families.

The women acknowledged that research and higher education have profound effects on the management of commercial activities. But they had not considered the potential of research and higher education in reducing the cost and improving the quality and management of value-added activities in the home.

This issue of *Illinois Research* is intended to make us all more aware of the complex interrelationships between basic human and physical resources and value-enhancing activities within our homes, the enormous economic and social significance of these resources and activities, and the great potential benefits from their improved management.

Donald A. Holt, Director, Illinois Agricultural Experiment Station

*H*ousehold Production: Concepts, Issues, and Challenges

Andrea H. Beller and Sheila Fitzgerald Krein

Historically, families and society in the richest to the poorest nations have benefited from the economic and social *value added in the home*. Families carry out activities vital to our well-being. If these activities are unsuccessful, social institutions must intervene. Income-maintenance programs; prisons and the court system; and the special agencies and programs to handle drug abuse, alcoholism, teen pregnancy, mental health, illiteracy, AIDS, and child abuse — all are examples of such institutions. How families manage their resources also affects economy-wide behavior through its impact on consumer demand, employment, the economy's human capital stock (people), and its physical capital stock (machinery, factories, stores, and finished and unfinished materials).

Concepts

Household production may be defined as *commodities* produced in the household with inputs of market goods and services and the time of household members. These commodities — good health, educated and responsible children, nutritious meals, financial management, a happy home, love, psychological support, and self-esteem — yield satisfaction for families.

Distinct from market goods and services, these commodities are produced and consumed by households, cannot be purchased in the marketplace, and have no market prices: This does not mean that these commodities are valueless.

The resources necessary for this production — income and time — are scarce and have competing uses. We are all limited to 24 hours a day to allocate among work in the marketplace, work in the household, and leisure time. Just like market goods and services, time has a cost. If we work an hour in the household, we forego the income that we could have earned in the labor market. That income could have purchased market goods and services to substitute for our time in producing household commodities.

Comparing household production to production by a firm can be illuminating. Firms combine inputs of land, labor, and capital to produce goods and services desired by consumers. Households, however, combine inputs of time and market goods to produce commodities desired by families. For any good or commodity, the existing technology of the firm or household ultimately determines the maximum amount and quality of output that can be produced with specified quantities of inputs. The household's technology is determined by its *human capital* — its ability, household management skills, and knowledge about how a particular commodity can be produced.

Human capital can only be acquired by investing time in formal or informal education and training that will enable us to function effectively in our complex, changing society. As with any other investment, the returns will not be immediate. They will come in the form of increased earnings in the labor market, increased output from household production, and increased satisfaction from leisure time. Building human capital means increasing the ability of each household member to reach his or her full potential.

Many people believe that the family's most important function is to invest in the human capital of its children by teaching skills, encouraging creativity, promoting positive attitudes, transferring values, and teaching how to manage their own and the family's resources. Much of this process occurs in the schools and on the job; but for infants and young children, the vast majority occurs in the home.

As a result, children are a time-intensive commodity. The time required to produce children of the caliber that families and society demand is also higher than required by other commodities. Significant money expenditures are also required for their food, clothing, shelter, transportation, and college expenses.

Issues

Measuring value added in the home. Because the output of the household production process is not sold, the challenge of assessing its value falls to the researcher. Several approaches have arrived at different and yet surprisingly similar estimates.

In 1978, using 1973 data, Reuben Gronau, an economist at the Hebrew University of Jerusalem, estimated the average value of household production in the United States at over $7,500 (over $20,000 in 1989 dollars). For the average family, he found household production to be equal to 66 percent of total family income. For a family with preschool children, household production can rise to as much as 86 percent of total family income.

This percentage is almost equivalent to family income after taxes — the income actually available for improving family economic well-being. The value of home production was another 20 percent higher in homes where the wife was not employed outside the home.

In 1984, using 1976 data, John Graham and Carole Green, economists at Rutgers University and the University of South Florida, respectively, estimated the average value of household production at $13,000 (over $28,000 in 1989 dollars). To arrive at an estimate of value added, $5,000 ($11,000 in 1989 dollars), we must subtract the estimated value of the goods and services used as inputs for this production.

These figures can also be used to estimate that household production's aggregate value would contribute another 33 percent to the nation's gross national product (GNP). In 1976, using wage rates for activities performed in the home, Janice Peskin, an economist at the Congressional Budget Office, found the aggregate value of the output of U.S. households to be 44 percent of the GNP.

Division of labor by gender. Typically, the wife has been the main household producer, while the husband has worked outside the home. This rigid division of labor by gender between the home and the market arose after the Industrial Revolution as an efficient use of the family's time. Men's earnings were higher than women's in the labor market. Women bore the children and were socialized to be productive in the home.

After World War II, however, real wages increased for all Americans, as did women's education. And recently women's wages have increased faster than men's. Consequently, as stated by Barbara Bergmann, an economist at The American University, women's time has become "too valuable" to spend it all in the home.

In some cases, the most efficient choice for the family — women staying home with their children — left women unprotected in the increasingly likely event of family dissolution. These factors have increased the incentive for women to enter and spend more time in the labor market and less time in household production.

How have families adapted to this change? Some families have simply reduced their household production. Other family members have substituted their time for that of the wife. Data from time-use surveys, however, have not shown large increases in the husband's household production time. The leisure time that has been sacrificed to maintain household production has often been the wife's. Families have also searched for comparable goods and services in the marketplace to substitute for their time. Convenience foods, fast-food restaurants, catalog sales, cleaning services, and nanny services — all have evolved in answer to this need.

Challenges

One of the greatest challenges to emerge from the revolution of women into the labor market is: Who will care for the children? Nanny services are realistic options only for the wealthiest families. Although many families *do* substitute goods and services for some of their own time —for example, day care, babysitting, and music lessons — it is very difficult to substitute for all of it if we want our children to reflect our values, goals, and to develop their human capital potential. Recent data show that more couples are opting to remain childless as a solution to this problem. From the perspective of society as a whole, however, this is not a realistic option.

Thus, we must improve the availability and affordability of quality child care outside the home. Providing maternity leave and parental leave is also an important aspect to caring for our children in an era when few women will devote their lives exclusively to household production.

Policy makers especially need to recognize the importance of value added in the home. If achieving this awareness requires attaching a dollar value, then we need to continue to improve our research methodology and data so that we can produce more precise, reliable estimates.

Another challenge is to help families better manage their resources. Extension home economics makes these skills available to all families on an equal basis, but it cannot and does not reach everyone.

If, as a society, we accept the importance of investing in research and education to improve the management of value-added activities in industry, why not then extend these investments to the home where all would benefit? This investment would certainly cost less than any remedial actions.

Andrea H. Beller, associate professor of family economics, and Sheila Fitzgerald Krein, visiting assistant professor of family economics, both of the School of Human Resources and Family Studies

The Changing Role of Women in Developing Countries

Kathleen Cloud

↑ Some Indian women prepare rice for storage.

© David Riecks

↓ An Indian woman sells vegetables.

© David Riecks

Almost all value-added production and processing occurs within the household in Africa and Asia's traditional agricultural systems. Food is processed at home. Women and girls spend two to three hours daily hand-pounding millet and corn or threshing and parboiling rice to preserve and improve its cooking quality.

They must also preserve food each year for the "hungry season," the cold or dry period when fresh food is not available. Food preservation techniques include parboiling, sprouting, and fermenting grains; pickling and preserving meats and vegetables in brine; and smoking and drying meats. These valuable techniques seem to have evolved independently in several parts of the world.

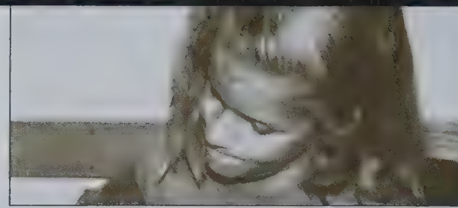
A recent study in Pakistan estimates that these and similar domestic activities, if counted, would produce a value-added equivalent of 35 percent of Pakistan's gross national product. Indeed, according to estimates from the International Labor Organization of the United Nations, national income in developing countries would increase between 25 and 50 percent if the economic value of all unpaid household activities were taken into account.

With increased development comes a shift in the types of production and processing that occur in the home. As women are released from the back-breaking work of pounding grain and carrying water, they can concentrate on improving food preparation and cooking. As income increases, consumption of dairy, poultry, and meat products also increases and the nutritional value and variety of the family diet improve.

Because they are not involved in farm food production, women in towns and cities are able to pursue value-added home activities such as cooking, sewing, crafts, laundry, and cleaning, as well as work outside the household. As schooling becomes more common and more important, time spent in child care also increases steadily for women.

Some economists characterize these increased investments in household health, nutrition, and education as value added to human capital production. Healthy, educated, and energetic men, women, and children can thus be viewed as both a cause and an effect of economic development.

Kathleen Cloud, director, Women in International Development, International Programs and Studies



The "Nation of Tomorrow": A Land-Grant University Experiment

Larry Nucci, Robert Hughes, Jr., Christine M. Todd, Gerald G. Gast, Mark A. Smylie, and Beverly J. McElmurry

As we enter the twentieth century's last decade, America's youth are failing because our society is failing them. Analyses of changes in the behavior of American youth over the past 30 years reveal some alarming trends. Self-destructive behavior, such as suicide and drug abuse, has increased. Destructive behavior that involves others, such as juvenile crime and disorder in schools, has also increased.

A third disturbing trend is a progressive decline in the academic achievement of American students. It is estimated by the U.S. Office of Education that 27 percent of all eighth-graders will not graduate from high school. Fewer than 50 percent of all high school seniors read at levels for moderate success in the work world. These three trends suggest that as a society we must examine our current investments in the children who will be our nation's future.

This crisis has prompted the Kellogg Foundation to issue a bold challenge to land-grant universities. The foundation has proposed creation of university and community partnerships to develop a comprehensive solution through enlightened public policy and community service based on quality research.

In January 1989, University of Illinois President Stanley O. Ikenberry encouraged faculty to respond to this challenge. Larry Nucci and a faculty team developed a project that would address the educational, familial, child development, and health needs of children in some urban Chicago neighborhoods.

The university received a grant from the Kellogg Foundation in September 1989 to initiate the "Nation of Tomorrow" project. Although still in the early stages, the project is a model for how land-grant universities can address the crisis facing American youth.

Project Overview

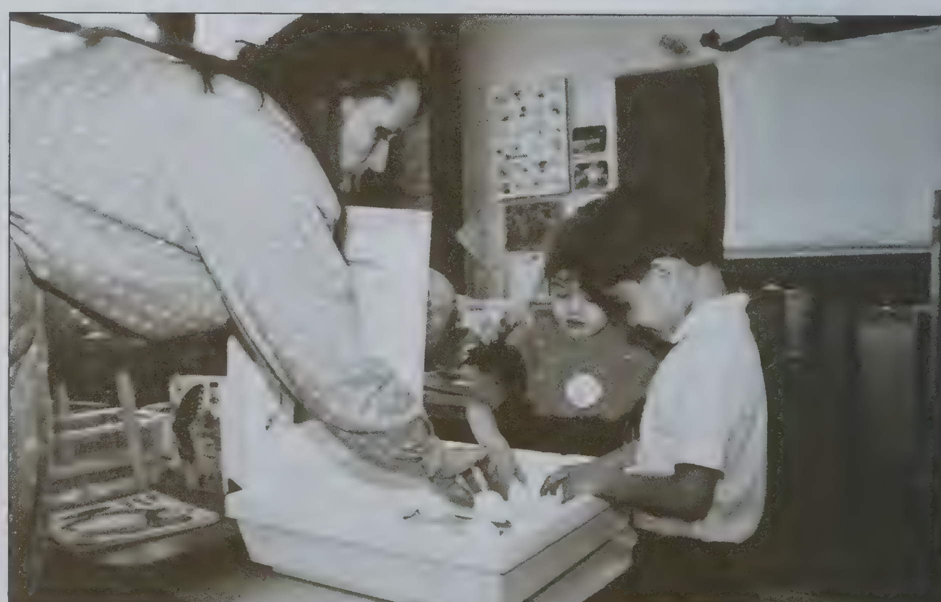
Four Chicago communities comprise the "Nation of Tomorrow." These communities are characterized by extreme poverty, families with many children, predominantly female head of households, and diverse ethnic backgrounds. A target elementary school in each community is the center of activities.

The project has four major objectives.

- To enhance learning opportunities for schoolchildren.
- To enable parents to contribute to their children's development.
- To increase the availability of high-quality child care and youth programs.
- To develop school-based primary health care programs as a part of community resources for the improved health of children.

Several project activities have been designed to achieve these objectives in cooperation with the schools, the families themselves, and the community.

School Enhancement. Efforts are under way to help practicing teachers develop their teaching skills and acquire additional knowledge. There are also plans to enlist school personnel to create a school climate conducive to teacher innovation and professional growth. University faculty and school



↑ A teacher and her students place eggs in an incubator.

→
A parent group works together on family well-being.

personnel will identify mutual concerns and collaborate to find and implement solutions through seminars, work groups, and innovative projects.

For example, there has been considerable concern about the literacy of children and the best strategies to develop their reading abilities. Each target school is analyzing this problem to identify possible solutions. As ideas and practices are developed, they will be collected and routinely shared to encourage their widespread dissemination and adoption.

Family Ties. The Family Ties program focuses on three aspects of family well-being: parent education, child care, and youth opportunities. The parent education effort involves creation of a video program by each community based on that community's goals, values, and parenting practices.

Parents, children, community social service providers, clergy, teachers, and other community leaders will work with university faculty to develop programs and delivery strategies that reflect each community's cultural values and effective parenting practices. This planning group will not only identify positive parenting models but also play a central role in designing and producing the actual video program. Upon program completion, parents in the community will be invited for training in how to assist other families in using the program.

Another component of Family Ties will focus on increasing the availability and quality of child care and youth opportunities in the community. Initially, the availability of these opportunities in each community will be documented. When gaps in service are identified, project staff will work with community organizations and parents to fill those gaps. In-service training for staff will also be made available in each community to enhance program quality. Programs for parents will help them locate such services within their own community.

Partners in Health. Improved health care for children and other family members is another project objective. There are three areas of emphasis.

- Implementing a primary health care program that integrates community outreach to ensure assessment, management, and prevention of health problems for schoolchildren and their families.
- Promoting collaboration between community resources for health care of schoolchildren through interagency networks and agreements.
- Assessing economic resources of families and agencies for sustaining effective and comprehensive school-based primary health care services for children. Each community will hire a school nurse and child health advocates from the community to assist children and their families with health issues.

Effective Change

During the past 30 years, many programs have addressed social problems. Along with some important successes, there have also been numerous problems.

For example, we have learned that visiting nurses or specially trained community residents can provide young mothers with information and skills that prevent developmental delays in children. Some intervention efforts, however, may result in feelings of helplessness and dependency. From an analysis of past programs of change, intervention strategies for this project were developed that preserve the successful approaches.

The unique aspect of the "Nation of Tomorrow" project may be *how* the work is conducted rather than the specific activities. The project is based on four general principles that guide the development and implementation of our efforts to address the issues facing youth in an urban environment: competence, partnership, empowerment, and an ecological perspective.

Competence. The project's foundation is that youth, families, and community institutions understand their own needs and have critical knowledge and abilities to meet those needs.

Many efforts at social change, however, take a deficit approach. Rather than assuming competence, a deficit model assumes that those for whom the programs were designed are not competent to address the situation. Thus, "experts" must solve the problems.

Our approach, however, identifies the strengths and resources of each community as a basis for building additional capabilities. For example, we know that some children overcome the disadvantages of poverty and succeed in school. In developing the parent education program, we want to identify strategies

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Even students work together on the project.

developed by parents that have led to the success of those children.

Partnership. Working relationships between the university and the community must be based on mutual respect and cooperation.

Too often, universities and other helping agencies have taken the approach that they have the answer to the problems within the community. While the community may contribute to planning, it was always clear that the helping agency would be the final decision maker.

With the "Nation of Tomorrow" project, however, we are committed to creating genuine partnerships between the university, the public schools, and the community. Established in the proposal's initial draft, these partnerships are also evident in ongoing project management.

Even before development of the proposal, there were meetings with school personnel and community leaders to discern their opinions about major issues confronting youth in their communities and how best to address those issues.

Additionally, an overall project advisory committee of school, community, and university representatives was created to provide basic project direction. Advisory committees were also established in each community to make decisions about plans and activities and to reach a consensus based on joint problem-solving.

Empowerment. The project strives to promote autonomy and self-reliance for youth, family members, and community leaders. The solutions are self-sustaining and not project dependent. For example, the project will not create its own child care program, rather the goal is to facilitate the ongoing efforts of existing community agencies and individuals to expand and increase the quality of child care programs.

Joint problem-solving will be the focus of the work with school personnel, community leaders, agency professionals, and parents. By working with people to maximize their control, we can reduce the feelings of despair and alienation that often prevent effective problem-solving.

Ecological perspective. Effective prevention programs must be intense, comprehensive, and address a broad range of factors that can affect the development of young people.

The "Nation of Tomorrow's" comprehensive ecological perspective includes not only the school environment, but also the family, peer groups, and the community. By working in each of these environments simultaneously, the program can support and strengthen its impact.

Implications

The overall goal of the "Nation of Tomorrow" is to determine how land-grant universities can work with schools and communities to address directly the problems facing American youth. During the next four years, the University of Illinois will examine how schools, families, peers, and community agencies can act upon the principles of competence, partnership, empowerment, and an ecological perspective to effectively improve the lives of the children of today and ultimately the nation of tomorrow.

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Maternal Diet and Child Health

M. Margaret Weigel

The future of families and communities is strongly linked to the health and well-being of our children. Low-birthweight babies of less than 5.5 pounds or premature babies are more likely to die during infancy. These babies also have a higher incidence of other problems — including birth defects, respiratory and other infections, growth and developmental delays, learning and behavioral disorders, and repeated rehospitalizations.

The arrival of babies with these problems often imposes severe emotional, psychological, and social burdens on their families. The economic costs can also range from tens of thousands to hundreds of thousands of dollars.

The costs to the nation are also high. In 1985, the National Research Council estimated that the total cost associated with caring for low-birthweight babies approaches $200 million a year. These babies comprise 11.5 percent of all infants born in the United States. The data suggest that reduction of only 2 percent in the low-birthweight rate would represent a savings of $28 million a year — even when the increased cost of providing adequate prenatal care for all pregnant women is taken into account.

Many factors can affect birthweight and other infant outcomes. But good maternal diet and overall nutritional status appear to be the most important prenatal care strategies that reduce risk of poor pregnancy outcome.

Pregnant women have increased needs for water, energy, protein, and several vitamins and minerals — including some B vitamins (especially folacin), vitamin C, calcium, iron, and zinc. Unfortunately, women do not always select foods that would give them the best nutrition for their dollar.

University of Illinois researchers are currently studying how a woman's age, cultural background, educational level, socioeconomic status, family residence patterns, and other factors can affect her dietary decision-making during pregnancy. They are also examining the effect of specific dietary nutrients, especially minerals, in maternal and infant outcomes.

Pregnancy-induced hypertension or high blood pressure, for example, affects one of every ten pregnancies in the United States. This serious disease is associated with increased maternal and infant mortality, preterm delivery, and low birthweight. The symptoms, however, cannot normally be treated with conventional antihypertensive drugs because their side effects can harm the mother and the fetus. In severe cases, physicians may induce premature delivery.

Investigators at the University of Illinois and their colleagues at the Universidad Central del Ecuador have been conducting studies to determine if adding two extra grams of calcium per day to the mother's diet can reduce her risk for pregnancy-induced hypertension and improve her chances for delivery of a healthier baby. It appears that calcium supplementation may be a safe, cost-effective way to reduce the risk of this disease in high-risk mothers.

In general, researchers have found that well-nourished mothers who eat a diverse, balanced diet and who gain appropriate weight during pregnancy have a greater chance of delivering heavier, healthier full-term infants. Even mothers whose dietary habits and nutritional status were poor before conceiving can greatly increase their probability of delivery of normal infants by eating well and gaining appropriate weight during pregnancy.

M. Margaret Weigel, assistant professor of community nutrition, Division of Foods and Nutrition, School of Human Resources and Family Studies

Education of Young Children Begins at Home

Judy S. DeLoache, Leann L. Birch, and Laurie F. Kramer

The word "education" typically evokes images of classrooms, desks, chalkboards, and apples for the teacher. Well before children start formal schooling, however, they learn from their first teachers, their families. At the University of Illinois, some researchers from the Division of Human Development and Family Studies study the learning that occurs in the American home during picturebook reading, family mealtimes, and sibling interactions.

Picturebooks. Picturebook reading teaches young children vocabulary and concepts. Through books, very young children learn about kings and queens, ocean liners and spaceships, and dinosaurs and dragons — people and things with which they have no direct experience.

Children also learn about books. At first they discover that pictures are representations or symbols for other things. Eventually, children understand that the wiggly marks on the page are also symbols

for sounds that are in turn symbols for meaning. Thus, literacy begins on the parent's lap.

When reading picturebooks to their toddlers, parents often have explicit, well-articulated goals. Most middle-class parents report that they want to instill a love of books and learning that they hope will last throughout their child's life.

Research by DeLoache shows that during picturebook reading, mothers use various strategies to direct the child's attention, to communicate information, and to elicit a display of the child's knowledge.

With very young children the interaction mostly involves labeling the pictures and providing some information about them. For example, "See the doggy. The doggy says, 'woof woof.'"

Questions for slightly older children are intended to get them to label and tell about the picture. For example, "What's that? What does the doggy say?"

As young children become more verbal and cognitively sophisticated, mothers communicate increasingly complex information and demand more. For example, a child may be asked to describe how something in a book relates to an actual experience.

Mothers thus provide a form of "cognitive scaffolding" that supports their child's maximum participation. Each child is constantly challenged at a level that assures success. This moderate degree of challenge optimally facilitates the child's cognitive development.

Mealtime. Important learning also occurs everyday at the family dinner table. Birch's research reveals that children learn what to eat, which foods to like and dislike, and when to start and stop eating.

Children's early eating experiences are crucial in forming food acceptance patterns. Although most children have an innate liking for sweetness and a dislike of sour, bitter tastes, other food acceptance patterns are learned. And parents usually structure these experiences in the home.

In general, children prefer familiar foods and do not quickly accept new ones. Providing repeated opportunities to sample new foods, however, increases the chance that children will like and accept a variety of foods — a pattern essential for adequate nutrition.

Unfortunately, this acceptance is not instantaneous and may require eight to ten experiences with a new food. In addition to structuring opportunities to try new foods, parents and siblings may also serve as models to encourage young children to sample new foods.

Parents typically want their children to eat primarily healthful foods. Many parents limit their own intake of fats, sugar, and salt and may attempt to impose such limits on their child's diet. But some practices that parents use to get their child to eat healthful foods may actually teach unhealthful eating patterns.

For example, many parents restrict their child's intake of sweets and savory snacks but then use these same foods as rewards, pacifiers, or treats. In the United States, sweets are often served at the end of a meal, and sweets and high-fat foods are part of our holiday meals and special treats. This association of foods with festive family social occasions may increase a child's liking for these foods. But if parents coerce their child to eat "healthy" but disliked foods, such foods may become even more strongly disliked. Coercive feeding techniques may enhance a liking for foods high in sugar and fat and foster a dislike for healthful foods.

Siblings. Young children also learn from older siblings. One study by Kramer followed a group of preschool children for several years from the birth of a younger sibling. These observations showed that the sibling relationship includes much teaching and learning.

For example, children were often observed teaching younger siblings a game, how to fasten a zipper, or their ABCs. Younger children were remarkable imitators of older siblings' behaviors. As they approached school age, older siblings often took more active roles as tutors or coaches to younger brothers and sisters. Younger siblings thus benefited from the older children's knowledge and experience. The older siblings also experienced the satisfaction and positive self-esteem that come from being effective teachers and nurturers.

Judy S. DeLoache, professor of child development and psychology; Leann L. Birch, professor of human development; and Laurie F. Kramer, assistant professor of applied family studies, all of the Division of Human Development and Family Studies

Family Diversity in the United States

Sharon Y. Nickols, Linda Asmussen, and James D. Oliver

Over the past 25 years, there have been tremendous changes in the family as a social institution and in the definition of the U.S. family. Although the United States has always been a pluralistic society, family diversity was recognized only recently. Previously, all family types were judged by a middle-class Euro-American model of the "ideal" family.

Today's contemporary family, however, reflects a multiplicity of living arrangements, gender roles, and relationships. To understand and work with modern families, we need to recognize this diversity. Each family has the potential to contribute to individual development and to the broader society. But rapid changes have made the family more vulnerable both economically and socially.

This article summarizes some of the major trends in U.S. families in recent years. We have drawn upon U.S. Census data and other sources for the statistics and trends reported here. We also identify policy implications that may affect the family's ability to add value.

Diversity of Family Structure

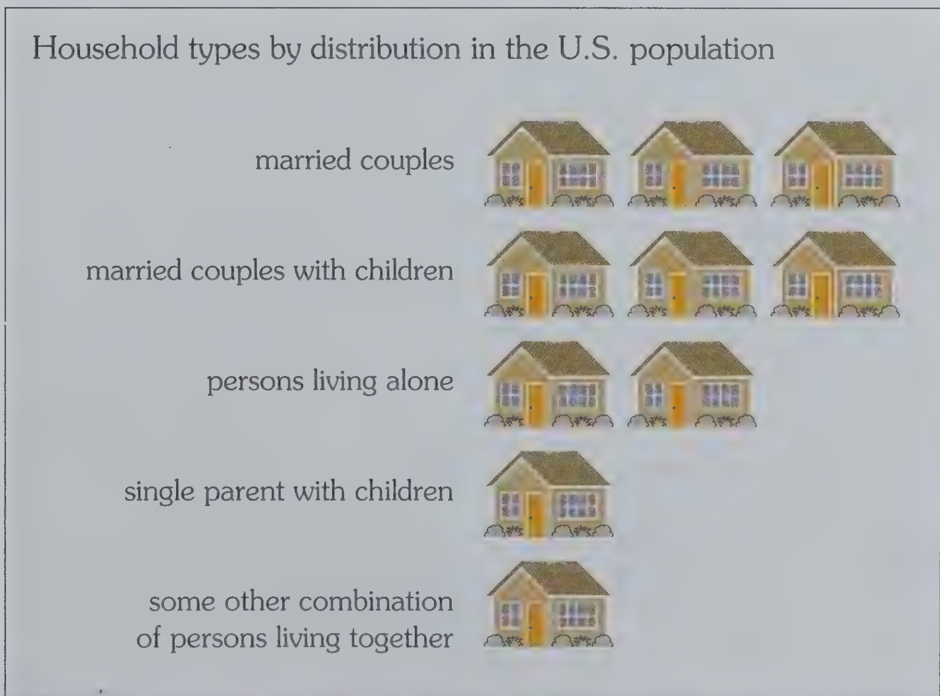
Typical household. In 1971, 81 percent of us lived in households that included a married couple. But only 73 percent of us live in such a household today.

To illustrate, let a hypothetical block of ten households correspond to the total distribution of U.S. household types (see figure). Six households — three of which have children present — are maintained by married couples. Two other households are maintained by persons living alone. One household is maintained by a single parent, one by other combinations of persons living together.

In 1986, married-couple families accounted for 83.4 percent of white families, 70.8 percent of Hispanic families, and 52.7 percent of African-American families. One-parent families, however, comprised 16.7 percent of white families, 29.1 percent of Hispanic families, and 47.2 percent of African-American families in the United States.

Divorce. Divorce affects the lives of approximately 2 million adults and more than 1 million children in the United States each year. In Illinois, the divorce rate in 1985 was 4.2 per 1,000 population, slightly less than the national rate of 5.0 per 1,000 population.

After a sharp increase between 1965 and 1980, the divorce rate in recent years has stabilized. Slightly more than one-half of all new marriages are expected to end in divorce. Most divorces occur after



seven to eight years of marriage — a pattern that is similar for white, Hispanic, and African-American populations.

Remarriage. Current statistics, however, indicate declining rates of remarriage. Five of six divorced men and three of four divorced women eventually will remarry if present trends continue.

Remarriage usually occurs within the first two to three years after divorce. Comparing divorce and remarriage rates for women by race indicates that there is variation among racial groups (see table).

Divorce and Remarriage Rates for Women*

	Divorce rate for first marriages	Remarriage rate after divorce
	. . . . percent	
African-American	30.6	45.7
White	26.7	64.3
Hispanic	19.5	55.1

* Data for women age 20 to 54 years of age in 1985.

Children and Their Families

Single-parent families. In 1981, approximately 20 percent of children below the age of 18 were living with one parent. The 1990 Census is expected to reveal an increase of these children — likely more than one-fourth of all households (26.5 percent). On the average, children spend six years in a single-parent family created by divorce.

Stepfamilies. Approximately one-third of all children born in the early 1980s will live with a stepparent during some part of their childhood. In 1987, there were approximately 11 million remarried families. There were 4.3 million stepfamilies (families that include children at home under the age of 18 who were born before the remarriage occurred). Stepfamilies comprised 6.7 percent of all families and 17.4 percent of married-couple families with children at home under the age of 18.

Pregnancy and birth. By age 19, one-fourth of all females have a baby. Eighty percent of these mothers are not married. The proportion of children born to unmarried mothers increased from 5 percent in 1960 to 19.2 percent in 1987 or 12 percent of white births and 55 percent of African-American births.

Illinois ranks among the five states with the highest incidence of infant mortality and low birthweight among the nonwhite population. For every 1,000 live births in Illinois, 12.4 infants die before the age of one year. One grim statement summarizes these dismal statistics — an African-American baby born in Chicago is more likely to die in the first year of life than a baby born in Costa Rica.

Changes in Gender Roles and Economic Status

Working mothers. A majority of married-couple families, 60 percent, have dual incomes. Women with young children are the fastest growing segment of women in the work force. In 1987, 50.8 percent of women who gave birth in the preceding twelve months were working. Employed mothers with preschool-age children numbered over 8 million nationally in the first quarter of 1990.

On the average, employed mothers' earnings in married-couple families with children are 41.3 percent of total family earnings, a significant portion. Thus, families have come to depend upon the earnings of both husband and wife.

Children in poverty. Despite modest increases in median family income in the mid-1980s, recent data on household income reveal that certain groups are losing ground. In 1987, one in five children lived in households with incomes below the poverty level.

The 1990 Census is expected to show that 25 percent of the nation's children are living in households with incomes below the poverty level. Among white children, one in every six is poor compared to more than one in every three Hispanic children and nearly one in every two African-American children.

Children are especially vulnerable to economic insecurity if they live in a household with a female single parent. Median family income of households headed by women is considerably less than half that of families headed by married couples or by men. Between 1979 and 1986, the number of jobholders who fell below the poverty level increased from 8.5 to 8.9 million nationally.

"Safety net" programs are reaching fewer eligible people today. For example, the Food Stamp program fails to reach one-third of those who are eligible; the Women, Infants, and Children (WIC) nutrition program serves less than 50 percent of high-risk, low-income women and children; and Aid to Families with Dependent Children (AFDC) went to only 60 percent of children in poverty in 1986, compared to 72 percent in 1979.

Implications for Family Policy in the 1990s

Recent trends in family characteristics reflect thousands of individual decisions in response to changing social and economic conditions. The cumulative effect of these decisions and other sociodemographic factors have markedly changed the profile of the U.S. family.

As families and personal relationships change, families will become even more diverse. Because families are process-oriented, they are constantly adopting new features and adapting to changes in the economy and governmental policies.

Policies and programs that once worked well may need adjusting in new situations. Policies and programs that work well with one population segment may need redesign to meet the concerns and needs of other populations. No one should know this better than the people of Illinois with our diverse geography, economy, and population distribution.

As the forces of change remake the economy, increasing opportunities in some areas and decreasing opportunities in others, some families can provide only the barest necessities for themselves.

Of particular concern for the future is the growing number of children living in households below the poverty level. Because they can do little more than meet daily survival needs, these households are severely hampered in their ability to add value to their children's lives.

Greater economic security can be achieved by several methods, some of which are discussed elsewhere in this issue of *Illinois Research*. To meet some of the critical challenges facing the family during this decade, U.S. policies and programs should focus on the economic well-being of single-parent families.

Specifically, some of the key issues that would add value to these families relate to

- Availability of affordable housing.
- Access to quality, affordable health and child care.
- Education and career training.
- Creation of job opportunities that provide adequate income and advancement.

Census data and large-scale surveys conducted by government agencies can provide an overview of trends in family composition and economic status. In-depth studies are needed to discover the intricacies of family decision making and relationships that provide value-added models of interaction.

Sharon Y. Nickols, director, School of Human Resources and Family Studies, and assistant director, Illinois Agricultural Experiment Station; Linda Asmussen, research associate, Division of Human Development and Family Studies; and James D. Oliver, associate director for urban programs, Illinois Cooperative Extension Service

What Has Happened to the "Old Folks at Home"?

John R. Kelly

The stereotype of aging is primarily negative and untrue: Youth is supreme, but from then on it's downhill all the way. The advertising media, recognizing "old folks" as a significant market, increasingly portrays them as active and vital. Ninety-five percent of those over age 65 live at home, not in institutions. They take care of themselves and each other and are members of families, neighborhoods, and communities.

Active oldsters. A new designation is "active oldster." Physically and socially active men and women in their 60s, 70s, and even 80s continue a variety of social, family, and home-based activities. Because more adults retire with adequate financial resources and viable health, they are able to build lives at least as satisfying as their preceding years.

A study I completed a year ago of recent retirees of a food-processing plant in Champaign, Illinois, painted a common picture of retirement. Most of those interviewed had retired within the past three years. They were getting on as well or better than they had expected. They had modest but adequate incomes and reasonable health.

These men and women had held routine jobs, had not been to college, were glad to be free of their work schedules, and were enjoying retirement. Their social worlds revolved around their families. Most of their activities were accessible,

↑ Pat Larson, yoga instructor, (bottom) leads a class at the Urbana Park District's Thornburn Center.

low cost, and home centered — activities that they had pursued before retirement and new ones that required additional time. New routines included a core of companions and activities punctuated by occasional special events and travel. Their lives were meaningful and satisfying. The only exceptions were those with health limitations or those who had recently lost a significant family member.

During retirement our need for challenge and accomplishment continues. There is no substitute for day-to-day sharing with others and engaging in meaningful activity. The result is healthier, happier, and less depressed old people, who are more satisfied with their lives and themselves.

Remember, these people have been productive. They have reared families, developed communities, produced goods and services, performed research, supported the government with their actions and their taxes, and, in general, contributed to society. They have every right to believe that they have done their share. When they expect to be supported in a reasonable quality of life, they are not being greedy but merely stating their right to a return on their life investment.

The "active old" are often the volunteers who operate referral centers, deliver meals and books to the homebound, and keep much of the community service structure going. They not only drive and care for grandchildren, but they are also frequently the caregivers for the frail elderly.

When they reach age 65, over half of American adults now have a parent living. They go on helping, sharing, and caring — often with greater intensity now that they are no longer bound to an employment timetable. And those who have a sense of being of value, of doing what is worthwhile for themselves and others, experience no decline in self-esteem. They know daily that they have been and are still productive.

Transition into frailty. Of course, this involvement does not go on forever. A higher proportion of older people will live to become relatively dependent. About half of those age 80 and over will spend some time in a care facility before they die. At any given time, however, a much larger proportion will be living at home. Some will share a residence; more, usually women, will live alone.

For many, this transition into frailty will be a gradual one. Geographically and socially, the range of activities becomes more constricted, more home-centered. Poverty and illness can accelerate this trend. Activities that require strenuous travel are dropped, and ones that can be carried out at or near home take on great significance. Although former companions and engagements are still important, it is just no longer possible to do everything.

Good news. So, what's the good news for this transitional period?

- Most communities now provide various services to sustain and enrich the lives of older people.
- The home itself is becoming an increasingly rich, stimulating environment. Cable TV and VCRs offer entertainment, education, information, debate, and stimulation. Fiber-optic cable will enhance these opportunities even more. Libraries may even add video selections to their book delivery services.
- The enriched home environment can be managed and personalized. It can become a social center for family, friends, and neighbors to meet.

Implications. Affordable and well-planned housing for older people must become a priority along with health care. There is no substitute for caring people who make it a priority to form social networks around those who are increasingly homebound. Even in their homes, older people continue to contribute their wisdom and experience to those who are willing to listen and care. And those who receive care can go on sharing their love.

John R. Kelly, professor of leisure studies and director, Office of Gerontology and Aging Studies

Remodeling This Old House

Joseph L. Wysocki

Americans are keenly interested in improving their older homes to include the amenities of newer homes. Growth in this segment of the construction market is expected to continue. Annual remodeling expenditures are expected to reach $289 billion by the year 2000, almost three times the 1990 projection.

The remodeling boom is a response to many factors. Vast increases in housing prices, high interest rates on new mortgages, and the costs associated with selling, buying, and moving — all have compelled consumers to stay in their present homes and remodel. In rural areas, especially for farm households, moving is not a realistic option. Remodeling, however, is an alternative, more affordable way to move up in the housing market. Many homeowners are using sweat equity to cut costs even further by doing some or all of the remodeling themselves.

The Study

In the late 1980s, housing researchers in the North Central states, supported by their respective agricultural experiment stations, analyzed past home remodeling decisions and future remodeling plans of 500 rural households. Families in Illinois, Iowa, Minnesota, Missouri, Nebraska, and Wisconsin were surveyed. Of these families, 52 percent had remodeled their homes during the past five years.

The survey indicated that the remodelers were between 30 and 49 years old, married with three- to four-person households, and had annual incomes over $30,000. These baby boomers, born between 1946 and 1964, comprise about one-third of the current U.S. population.

Remodeling changes. Table 1 presents the distribution of the various changes. Both interior and exterior appearance changes were the most popular,

Table 1.
Home Remodeling by Rural North Central Households

Remodeling Project	*Percent*
• Changed interior appearance	59
• Changed exterior appearance	58
• Changed mechanical system	51
• Improved energy efficiency	40
• Added outdoor living space or storage space	34
• Ceased use of existing space	28
• Converted unfinished space	17
• Added indoor living space	10
• Changed use of existing space	9

Table 2.
Home Remodeling Planned within the Next Five Years by Rural North Central Regional Households

Remodeling Project	*Percent*
• Improve interior appearance	28
• Improve exterior appearance	24
• Add energy conservation features	14
• Change use or function of existing space	10
• Add outdoor living space	9
• Change mechanical system	8
• Convert unfinished space	8
• Add interior space	6

59 and 58 percent, respectively. Kitchen and bathroom remodelings dominated interior changes, 43 and 38 percent, respectively. Exterior changes included new roofs (29 percent), siding (23 percent), windows (25 percent), and landscaping (29 percent).

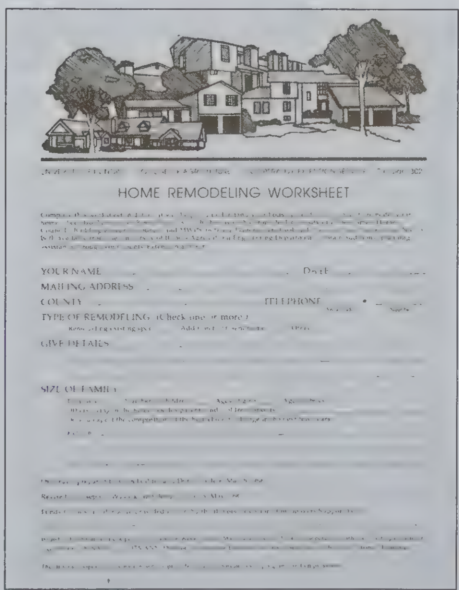
Fifty-one percent of the households surveyed changed their home's mechanical system. Of these changes, 64 percent were to home heating systems. Forty percent of the households improved their home's energy efficiency. Significantly fewer households had ceased use of space — closed off a room or an entire floor — added indoor living space, or converted unfinished space. The most frequent change to existing space decreased the sleeping area and increased recreational space.

Outdoor living space was added three times as often as indoor living space, 34 and 10 percent, respectively. Fifty-four percent of the sample added decks.

The future. About 30 percent of the households surveyed plan to remodel in the next five years. The future plans of the total sample (Table 2) seem consistent with the changes indicated in Table 1. Improving the interior and exterior appearance were the top remodeling changes planned, 28 and 24 percent, respectively, followed by adding energy conservation features, 14 percent. A small percent of respondents, 10 percent, planned to change existing space. Even fewer planned to convert unfinished space or add indoor living space, 8 and 6 percent, respectively.

Program Response

Total housing costs, the largest household budget item, encompass over 33 1/3 percent of a household's income and 50 percent or more of the income for elderly and limited-resource households. Housing affordability, the major housing issue today, is the focus of extensive programs in Illinois. One major component of these programs is to assist households — especially rural, elderly, and limited-resource households — with decisions related to remodeling their homes to best suit their needs and resources.


HOME REMODELING WORKSHEET

YOUR NAME DATE
MAILING ADDRESS
COUNTY TELEPHONE
TYPE OF REMODELING (Check one or more)
GIVE DETAILS

SIZE OF FAMILY

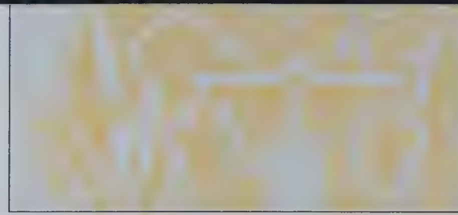
The findings of this survey support the popularity of remodeling as a viable, affordable housing alternative. The findings also suggest kitchen and bathroom remodeling projects as possible areas of program emphasis.

More than just a place to plan and prepare meals, the kitchen in many households is the center of activity. It functions as an office, a dining area, and a place for the children to do their homework.

The popularity of bathroom remodeling can be attributed to our growing interest in health and fitness. Many homeowners have remodeled their bathrooms to accommodate a sauna and exercise equipment. Others have incorporated this equipment in large master bedrooms or a separate room.

Several University of Illinois publications can help consumers plan their remodeling projects. The bibliography in this issue includes several of these sources. Remodeling workshops are also offered periodically through county Extension offices.

Joseph L. Wysocki, assistant professor and Extension housing specialist, School of Human Resources and Family Studies



Money Matters: Family Financial Management Makes a Difference

Vicki Schram Fitzsimmons

In the summer of 1968, Susan and Don Brown* were married in the central-Illinois city of Peoria. Phyllis and Bob Thompson* were married about 60 miles to the southeast, in Decatur. Both couples were in their early 20s and were high school graduates with annual incomes of approximately $15,000. Don and Bob were employed in semiskilled occupations; Susan and Phyllis had clerical jobs. Neither couple owned a home, and their net worth was very similar.

As is the case with many newlyweds, the Browns and the Thompsons were faced with setting up a household with few resources. During their first years of marriage, both couples had to make some important decisions about something altogether new and challenging — managing *family* finances.

Although the couples began married life in very similar circumstances, by 1980, the year of their twelfth wedding anniversaries, their financial positions were considerably different. By then, both couples had increased their incomes to the same level, about $26,000. But the Thompson household still had two income earners, while Don had become the only income earner for the Browns. The Thompsons needed two incomes to match what Don Brown earned alone. This would appear to have given the Browns an edge in accumulating more wealth because Susan had time to produce nonmarket income in the home, such as growing and preserving vegetables, sewing clothes for the family, and planning and preparing meals to avoid the expense of eating out. All these activities could have helped to stretch the Browns' income. Thus, more money could have been available for saving. This, however, was not the case.

Even though their incomes were the same, the two families' net worths (assets minus liabilities) were markedly different. In fact, excluding their personal residence, the Browns in 1980 had $0 net worth, while the Thompsons had $14,500.

Although both couples were homeowners, insufficient information about the value of their homes made a comparison difficult. Asset and liability information on other components of the couples' net worths (for example, the value of automobiles and other durable goods, savings, and investments) was used to calculate net worth exclusive of personal residence. This value is an important indicator of available resources, savings for goals other than buying a home, and ability to cope with financial adversity.

What Made the Difference?

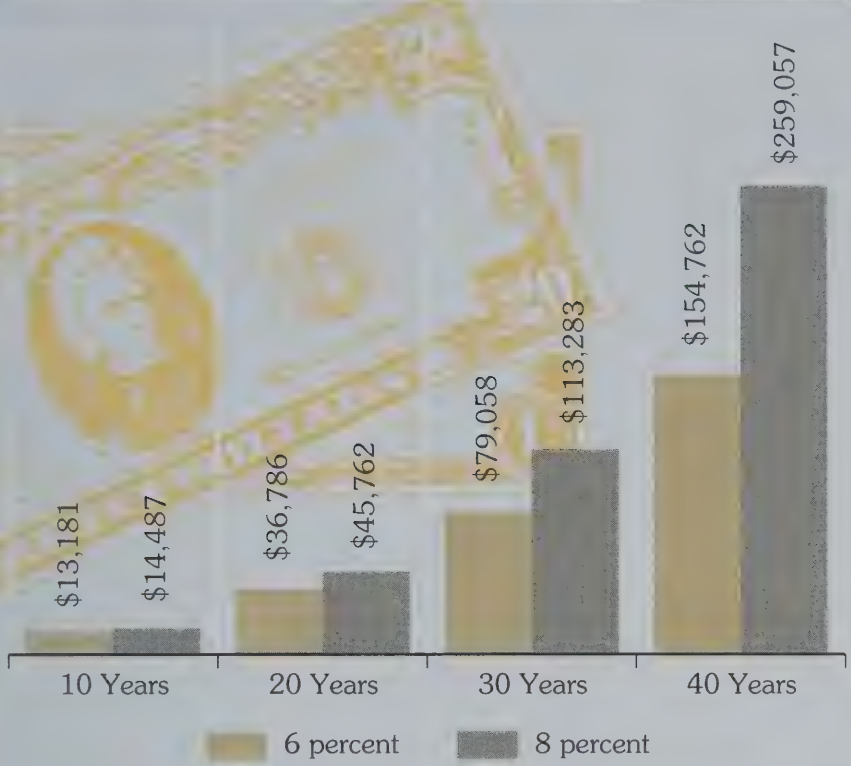
To gain insight into family finances, University of Illinois researchers conducted a study of about 200 newlywed couples in Peoria and Decatur from 1968 to 1981. The Browns and the Thompsons were among the families studied, and they represent the average respondents in the survey.

The two couples' saving and spending patterns illustrate the situation for many young families. Given the same initial circumstances, some do well financially while others do not. For some families, education makes the difference; those with higher education usually earn higher incomes. Neither the Browns nor the Thompsons continued their education beyond high school. Number of children can make a difference. The more children a family has, the more stress is put on family income: Both couples had two children, so this factor did not account for the difference either. Death of one spouse or divorce can have a debilitating effect on family finances, but neither occurred for the couples under study. Other factors affecting a family's financial situation include inheritance, disability, and job layoff. (These factors may have accounted for some of the difference in net worth for the Browns and Thompsons, but information was not collected on these factors.)

Attitudes about spending and saving can indicate subsequent financial management behavior. The University of Illinois survey data show that the Browns and Thompsons had different attitudes about finances. As newlyweds, the Browns did not plan to save any particular amount each month, while the Thompsons did.

The best way to have savings is to treat it as a regular budget category and to save a set amount each month. Regular savings over a long time is the key to accumulating money for a secure retirement as well as interim goals. Saving over a long period can result in much greater total savings, largely due to

* *Not their real names.*



Amounts attained by saving $1,000 each year after 10, 20, 30, and 40 years at interest rates of 6 and 8 percent.

Source: Lang, Larry R., and Gillespie, Thomas H. 1984. *Strategy for Personal Finance*. (3d ed.). New York: McGraw-Hill.

regular saving and compounding interest (see figure).

The Browns got into trouble by deciding early on to save whatever was left at the end of the month. Financial educators cite this as poor financial management. When a family saves whatever is left over, the amount tends to be irregular and small, if anything at all. Unfortunately, people tend to spend all they have readily available.

By contrast, the Thompsons said they would try to keep expenditures down so they could save. Saving often means lowering consumption of goods and services so money is available to save. Changes can be made in quantity, quality, or variety of goods and services, which can free up dollars for saving without seriously lowering the family's standard of living. For example, choosing private-label products over national brands can result in significant savings. Choosing inexpensive hobbies can result in savings; more expensive hobbies can be pursued later in life, when income is greater.

Financial Management: A Major Task

Financial management, one of the major tasks families have, varies by stage in the family life cycle. Newlyweds need to sort out how to handle finances — who will pay the bills, how financial decisions will be made, and so on. Much knowledge about housing, insurance, investments, taxes, and durable purchases needs to be acquired and used to make appropriate financial decisions at any stage of the family life cycle.

The specific kinds of knowledge will vary. For example, young couples may need to know how to shop for rental housing; middle-year families may need to focus on home ownership and its related costs; elderly families may benefit most by concentrating on how to use home equity for retirement income.

Each family may require large sums of money to fund a home, to raise children and pay for their education, to buy durable goods, and to secure retirement income at the very least. To accumulate these large sums, families must make spending and saving decisions to make the most of their resources. As income and expenditures change, financial management continues to play an important role.

Families can learn about financial management through a variety of methods. Reading about the topic is an easy way to get started (see bibliography on page 25). Attending financial management classes and seminars and consulting with financial planners and educators are also helpful.

Financial management skills are developed by applying accumulated knowledge and managing finances. Choosing types and amounts of insurance appropriate for one's particular family and financial situation is one example. Often, more insurance can be obtained for the same amount of money by choosing appropriate life, health, property, liability, and disability insurance.

For example, one can acquire more protection for the same amount of money by purchasing term rather than whole-life or universal insurance. This is one way families with few resources can get the most life insurance protection possible. Families often need more liability protection than they think they can afford. At the same time, they usually have a low deductible of $50 or $100 on their property insurance. Raising the deductible (to an amount still within emergency reserves) results in a lower premium. The savings can be used to purchase higher liability coverage.

Relating Financial Management to Value Added in the Home

Family financial management affects more than just the pocketbook. If done correctly, it can improve a family's net worth and provide greater command over goods and services. Sound financial management enables a family to improve economic well-being. But it also adds a greater feeling of control, an important factor in dealing with economic adversity.

Another benefit is improved family relationships. Good communication and development of mutual goals are important aspects of successful financial management, and these enhance both spousal and parent-child relationships.

Quantifying the value added from family financial management is somewhat difficult. But one way to get some idea of its effect, is to speculate on the change in personal savings. Assuming that people do not save regularly, and do not spend effectively, improved financial management could result in increased savings.

Given the low personal savings rate in this country (4 percent in 1986, compared to 12.5 percent in West Germany and 21 percent in Japan), an increased savings rate could have a profound impact on the overall economy.

Before calculating the possible change in overall personal savings, we need to know whether people already save regularly. The answer is a resounding *no*. In 1989, the author and another University of Illinois researcher, Jeanne Hafstrom, surveyed rural households in Illinois.

When asked how often they saved regularly for goods, only 28 percent of the respondents said they did so "most of the time." The remaining 70 percent did not save at all or did so on an irregular basis.

Further, almost 50 percent of the respondents were dissatisfied with the amount of money they were able to save, and 18 percent had mixed feelings. Given this information, it seems likely that savings could be increased through improved financial management.

An individual or a family can use a future value table (like the one shown) to calculate the effect of increased monthly savings on total accumulated savings. For example, saving $100 a month for 20 years and consistently earning 8 percent interest would result in $54,912. By saving just $10 more each month, the value in 20 years would be $60,403, a difference of almost $5,500.

On a national level, personal savings amounted to $203.7 billion in mid-1989. If, through better financial management, people could increase their savings by just 1 percent, the aggregate increase would be $2.37 billion for the nation. A 10 percent increase would yield $20.37 billion. Further, an increase in this kind of nationwide saving would also increase national income and employment. Savings are invested in the production of goods and services, which results in more jobs for people who then have more money to spend and save. All of this has the potential to expand the economy and increase national income.

Thus, the value added by personal financial management has an enormous potential for improving the economic well-being of families and for increasing national wealth. Financial management education throughout the family life cycle is an important step in helping families and the nation to realize this potential.

Future Value of Savings of $1 per Year at Selected Interest Rates

Year	6%	7%	8%	9%	10%	12%
1	1.000	1.000	1.000	1.000	1.000	1.000
2	2.060	2.070	2.080	2.090	2.100	2.120
3	3.184	3.215	3.246	3.278	3.310	3.374
4	4.375	4.440	4.506	4.573	4.641	4.779
5	5.637	5.751	5.867	5.985	6.105	6.353
6	6.975	7.153	7.336	7.523	7.716	8.115
7	8.394	8.654	8.923	9.200	9.487	10.09
8	9.897	10.26	10.64	11.03	11.44	12.30
9	11.49	11.98	12.49	13.02	13.58	14.78
10	13.18	13.82	14.49	15.19	15.94	17.55
11	14.97	15.78	16.65	17.56	18.53	20.65
12	16.87	17.89	18.98	20.14	21.38	24.13
13	18.88	20.14	21.50	22.95	24.52	28.03
14	21.02	22.55	24.21	26.02	27.98	32.39
15	23.28	25.13	27.15	29.36	31.77	37.28
16	25.67	27.89	30.32	33.00	35.95	42.75
17	28.21	30.84	33.75	36.97	40.54	48.88
18	30.91	34.00	37.45	41.30	45.60	55.75
19	33.76	37.38	41.45	46.02	51.16	63.44
20	36.79	41.00	45.76	51.16	57.28	72.05

Source: Garman, E. Thomas, and Raymond E. Forgue. 1988. *Personal Finance* (2d ed.). Boston: Houghton Mifflin Co.

NOTE: $FV = A_n \times F$
FV = *future value*
A_n = *amount* (savings) for *n* periods
F = *factor* of future value (given a certain interest and *n*)

Vicki Schram Fitzsimmons, associate professor of family and consumer economics, and graduate programs coordinator of Division of Consumer Sciences, School of Human Resources and Family Studies

Illinois Model Farm and Family Improvement Project

*MaryAnn Paynter
and Duane E. Erickson*

"We've seen some real changes on our farm. We were in trouble financially. By setting goals...and working a little harder, we were able to [improve] that situation a lot," says Kent Hildebrand, a Bureau County farmer. His wife Karen works on the farm and also has a full-time job. Their three children are college graduates. The Hildebrands wanted to get out of debt and plan for retirement.

The program. The Hildebrands are one of six farm families participating in the Bureau County Farm and Home Improvement Project. With the help of the five-year program, the Hildebrands were able to refinance their farm at a more favorable interest rate. The program developed by an interdisciplinary team of Extension specialists and advisers was designed to strengthen the management skills of farm families.

The program also supports two Cooperative Extension Service National Initiatives. The family and economic well-being initiative includes the critical issues of providing help during family disruption and dislocation and of providing family financial stability. The agriculture initiative emphasizes farm competitiveness and profitability.

Project objectives were approved by the county Extension Councils. Each of six competitively chosen families would

- Learn to apply research findings to business and family management.
- Strengthen record-keeping and financial management skills: enroll in the Farm Business Farm Management (FBFM) program and develop an annual comparative farm business analysis.
- Develop farm production plans — including soil testing, crop and fertility planning, and using other innovative methods and technologies.
- Identify preferences and determine priorities for farm and family goals.
- Make a five-year management plan using individual, family, and community resources to accomplish goals.
- Participate in group demonstrations to share information and practices with the community.

All project families agreed to videotape interviews. The edited video, "The Future is Ours: Managing Farm Family Goals," documents the positive attitudes of these families toward program involvement. The video can also be used to motivate other farm families to participate in goal-oriented management.

Results. The six families' financial analyses indicate increased growth each year. Farm record summaries for program participants suggest net returns above the average of comparable FBFM cooperators in Illinois. After three years of the program, soil tests obtained for each participating farm revealed increased pH, phosphorus, and potassium test readings. Improved family and economic well-being resulted from families adopting fertilizer recommendations, financial planning, farm and family goal-setting, and estate planning.

Specific practices adopted by program participants include changes in record-keeping systems, revisions in insurance programs, improvements in financial management techniques, increased decision-making to set priorities and to make plans, and identification of goals to provide direction for progress. The families believe that goal-oriented management requires communication and commitment, that goal revision is necessary when a family's situation changes, that farm and family goals are intertwined, and that written goals are more effective than verbal ones.

The project reflects the spirit of its participants. Family members in the program share equally in the discussion and implementation of family and business goals. Agriculture and home economics resources are also available from county and state Extension staff. The families then make decisions based on values, facts, and personal preferences.

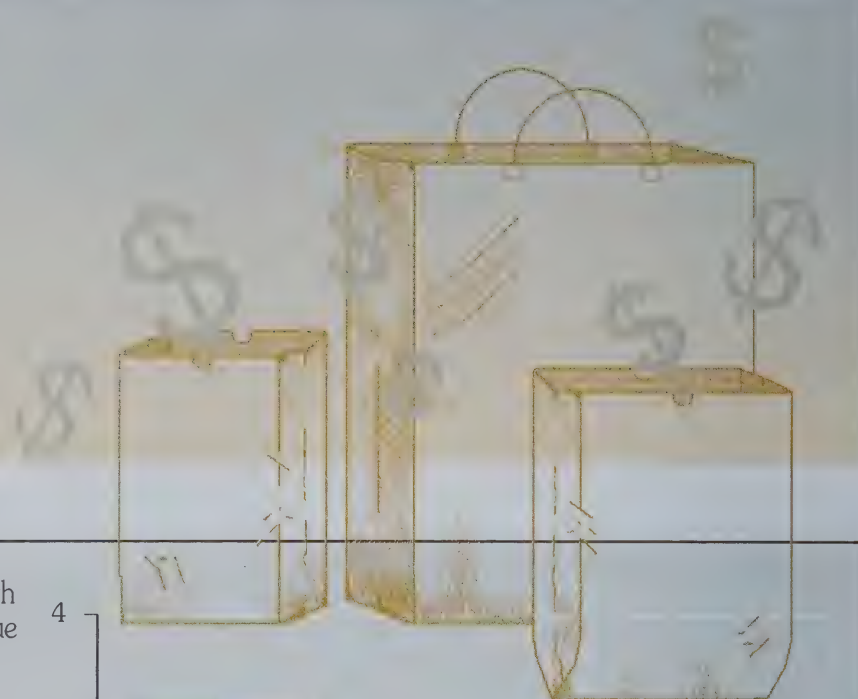
They are now sharing what they have learned with other families in their communities. This project's success is the direct result of the outstanding contributions by these six Illinois farm families and the professional leadership provided by the Extension team. Says Karen Hildebrand, "It's fun and exciting to see what we had planned to do and what we were really able to accomplish!"

To purchase the video, write the authors at the School of Human Resources and Family Studies, 905 South Goodwin Avenue, Urbana, Illinois 61801. Copies are also available to borrow from Illinois county Extension offices.

MaryAnn Paynter, assistant professor of family economics, School of Human Resources and Family Studies, and Duane E. Erickson, professor of agricultural economics

↑ Bureau County's Todd and Gerry Frank share news and dinner.

Value: The Consumer's View on Apparel Retail Stores



Michelle A. Morganosky

A major factor in whether or not consumers patronize a particular apparel store is how they perceive the "value" that they are offered. Consumers usually try to maximize the trade-off between what they "get" and what they have to "give" in the exchange process. Product quality is very important in this process.

In recent studies at the University of Illinois, interviews were conducted with more than 1,200 consumers throughout the United States. The studies evaluated the relationship between quality and price offered at various types of apparel retail stores.

Consumers' evaluations of this relationship are especially important now due to major shifts in the apparel retail market structure. Traditional forms of retailing, such as department stores, have existed for more than 100 years. But today's consumers are also confronted with newer forms of retailing such as off-price stores and manufacturers' outlets.

During the 1980s, off-price apparel stores and manufacturers' outlets showed significant market-share gains, while department stores lost market share. One explanation is the ability of these newer retail types to deliver value to the consumer through maximization of the price-quality relationship.

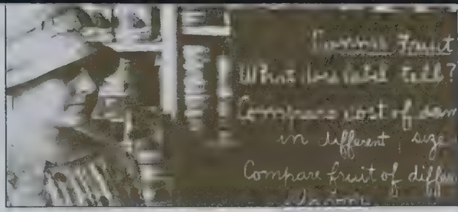
Data from a recent study indicate that consumers perceive apparel *quality* at department stores to be highest. Because they perceive *price* at department stores to be even higher, the trade-off between quality and price is less than ideal.

Consumers rate value at different types of retail stores.

At off-price stores and manufacturers' outlets, however, consumers perceive lower prices in relation to quality. Off-price stores and manufacturers' outlets both emphasize name-brand apparel at lower prices than department stores. Because off-price stores purchase merchandise through nontraditional methods, such as buying manufacturers' excess production, they can offer lower prices. Manufacturers' outlets are owned by apparel manufacturers and thus can channel excess merchandise more directly to consumers than other forms of retailing.

Nontraditional retail forms, such as off-price stores and manufacturers' outlets, will most likely continue to experience market-share gains as consumers seek value in the exchange process.

Michelle A. Morganosky, associate professor of apparel marketing, Division of Consumer Sciences, School of Human Resources and Family Studies



Improving Life Management Skills and Technology

Donald A. Holt

Each of us knows individuals and families, within our own income stratum, who manage their personal resources exceptionally well. They create and maintain an unusually good physical, intellectual, and emotional environment for themselves and their families. As a result, they enjoy a high quality of life. But given the same basic resources, others create for themselves and their families a living hell, whose repercussions are felt for generations.

Most people, however, range between these extremes, keenly aware that things could be better but unable to improve them. Although luck may play a role in some of these circumstances, the differences in quality of life generally result from how individuals and their families manage life's basic resources, practices, and technologies.

Skills. The major areas that require good management skills are nutrition, health, housing, clothing, finances, relationships, and personal development. Some of the services associated with these areas include food selection and preparation; maintaining personal health and appearance; home improvement and maintenance; clothing selection, construction, and maintenance; personal and family financial management; scheduling, mutual support, conflict management, and personal counseling; and child care and education within the home.

These activities constitute a vast hidden economy of value added in the home. If these services had to be purchased outside the home, their total cost would equal 0.8 to 1.3 times the gross national product (GNP). Food, clothing, and housing services alone have been estimated at 0.44 times the GNP. Of course, these estimates do not include the value of those intangible services rendered in the home such as mutual psychological support and nurture of families.

Given the universal need for services rendered in the home and their enormous economic and social value, even a minor improvement in managing these activities would have a great positive impact on both the national economy and the quality of life. For example, a modest improvement in family financial management would result in huge increases in investment in both public and private enterprises and a corresponding reduction in the national debt, thus facilitating the resurgence of American competitiveness in the global economy.

National problems. Many current concerns identified as major national problems relate to management of human and economic resources within the home. These problems include homelessness, drugs, alcoholism, teenage pregnancy, AIDS, divorce, crime, poverty, illiteracy, alienation, food safety, smoking, stress, heart ailments, cancer, eating disorders, malnutrition, and numerous others. These problems, many preventable, cause great personal misery. Perhaps even more important, they result in missed opportunities for personal development, contribution, success, fulfillment, and happiness. Thus far, we have not found ways to avoid this incredible waste of human potential.

Benefits of research and education. Almost everyone accepts that research, education, and decision support are vital to improving the management of value-added activities in commerce and industry. Publicly supported research and educational activities improve commercial operations through improved technology and by providing new, better ways to manage operations.

Publicly supported research, education, and decision support also benefit the general public by fostering competition and improving

> "Home, what is it? Webster says home is one's dwelling house. Shall we confine ourselves to this definition? Does not home mean more to us than simply a place of habitation? Neither do four walls make a home. No, more than this is required. Home means a generous supply of nature's bounties, carefully arranged and tended; it means intelligence at the workstand, it means diligence at the book; it means love at the hearth; it means devotion at the altar."
>
> *Miss Mattie Coto, Huntingburg, Indiana, in an address to the 1903 Dubois County, Indiana, Farmer's Institute*

↑ An early lesson about value added in the home.

productivity and efficiency of commercial operations. One excellent example is the unprecedented success of U.S. agriculture in providing a high-quality, affordable food supply for Americans.

Because they help people increase their productivity, public research and development often foster competition in the commercial world. Late adopters of improved technology may thus be at a competitive disadvantage. A vigorous, national program of research and development on value-added activities in the home, however, would benefit everyone. The program would focus on deriving maximum benefit from existing resources rather than competing for additional resources.

The Land-Grant Model

The institutional structure of agriculture is our nation's most successful model for publicly supported research and educational activities. A uniquely effective institutional structure resulted from the creation of the land-grant and 1890s institutions (Morrill and Evans-Allen acts), state agricultural experiment stations (Hatch Act), Cooperative Extension services (Smith-Lever Act), and integration of the latter two into the former.

Within these unique institutions were mechanisms to conduct research leading to new technology and improved management, to transfer this technology and information to potential users, and to educate and provide decision support for users. Both formal and continuing educational needs were addressed.

A modest investment of federal funds to create and maintain the land-grant and 1890s institutions triggered and fostered the development of a much larger, more powerful agricultural research and development infrastructure than could be supported by federal funds alone. For example, federal formula funds now provide about 12 percent of the support for the agricultural experiment station system. The rest comes from state and other federal sources, the private sector, and product sales and services from research operations at the experiment stations.

The unique institutional structure of U.S. agriculture propelled our nation's agricultural enterprise into world preeminence and helped it maintain that position for more than a century. The unprecedented success of scientific agriculture provided the economic base for the United States to become the world's dominant industrial force. It seems appropriate to apply this successful model to improving value-added activities in the home.

Problems Facing Home Economics in Land-Grant Institutions

Although state agricultural experiment stations and Cooperative Extension services originally focused on production agriculture, their responsibilities have broadened over time to include many of the home and family concerns mentioned earlier. The home economics programs, however, never received much research support. The modest level of federal support available and production agriculture's tremendous demands for information made it impossible for agricultural administrators to shift much institutional support, including formula funds, to other needs.

Administrators are also reluctant to weaken or destroy existing programs — many of which are extremely productive, useful, and strongly supported by various client groups. Building new programs in different areas, regardless of their potential is difficult. The research programs within our School of Human Resources and Family Studies are the latecomers among programs in the University of Illinois College of Agriculture.

Only twelve of about 165 full-time equivalent scientists conduct home economics research in the College, supported by \$1.6 million of the College's \$30.4 million total research expenditures. The quality of the home economics programs is excellent, but they are a mere drop in an ocean of problems and opportunities. As long as the Illinois Agricultural Experiment Station is expected to conduct programs of ever-widening scope with static or declining institutional funding, this situation is not likely to improve.

Another problem is that the formulas used to allocate federal resources to state experiment stations and Extension services are inappropriate to support programs that address the needs of an urban population. Factors such as number of farms and farmers are the basis for existing formulas. Formula funds or other institutional funds appropriated to create a research and Extension infrastructure for home and family concerns should be allocated to states in proportion to population.

Over the years, Cooperative Extension services were able to shift some resources to programs focused on family and home concerns. Unfortunately, Extension is not adequately supported to extend these unique educational programs much beyond the rural communities. Also, the experiment station system has not been able to provide Extension people with a sufficient research base upon which to build adequate educational programs on home and family topics.

Applying the Model

The agricultural experiment station system and the Cooperative Extension services networks have the potential to both strengthen essential traditional agricultural programs and create new programs for home and family renewal, without creating new institutional bureaucracy. Land-grant universities provide an excellent setting for basic and applied research and educational programs. The state agricultural experiment stations and Cooperative Extension services have remarkably efficient, highly decentralized systems of resource allocation. In fact, they have the best accounting and management information systems available to any government agencies.

The administrators of state agricultural experiment stations and Cooperative Extension services have statewide administrative responsibilities. Because they can allocate formula funds to qualified persons within any public institution or agency, administrators are in a position to marshal the best public resources available to address public needs and opportunities. Because of their close cooperation with the private sector, the best private resources can be brought to bear on these needs and opportunities as well.

Historically, state agricultural experiment stations and Cooperative Extension services have been involved in research and education programs involving home and family concerns. They have experience in managing these programs, however modest they have been in the past. With a new source of funds, earmarked for research and continuing education programs that address the needs and opportunities within home environments, the existing institutional structure could usher in a new era in quality of life.

Conclusion

A bold, new home economics research and education program, supported initially by public funds, must be launched. It is justifiable on economic grounds alone but has enormous potential social benefits as well. Of course, university administrators are expected to seek support for new programs. Therefore, our requests are often seen as self-serving. We never receive that support, however, unless others outside the institution share our hopes and dreams for these programs. I hope there are others who see the potential I describe here.

To reinforce the ideas presented in this article, the following observations can be made.

- As a nation, we spend tens of billions of dollars annually to improve the technology and management of delivering death and destruction.
- As a nation, we spend hundreds of billions of dollars annually for treatment, care, punishment, and rehabilitation of people afflicted with preventable problems that originate in the home.
- As a nation, we suffer losses of hundreds of billions of dollars annually due to the unachieved potential of human beings whose health, mental capabilities, and attitudes are damaged or otherwise limited by their home environments.

Although these observations are disturbing, they also provide some perspective on the need and opportunity to employ our most constructive, positive, and powerful public institutions — namely, our land-grant institutions — to address the most basic human needs.

Donald A. Holt, Director, Illinois Agricultural Experiment Station

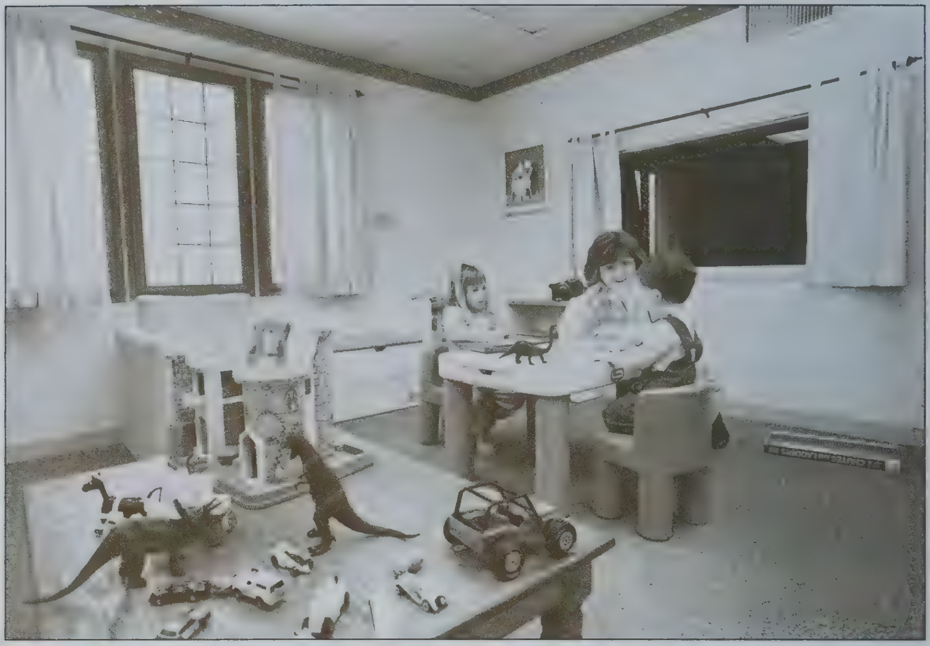
In Progress

Historic Costume Collection Steps Out

The Nettie Lou Samuels Couture and Linen Collections were recently unveiled. The collections were gifts to the Historic Costume Collection of the School of Human Resources and Family Studies. Judith Ikenberry, wife of the University of Illinois president, hosted 250 guests at a high tea honoring Nettie Lou Samuels of Decatur.

A loan of mannequins and personnel from the former Robeson's Department Store of Champaign made it possible to showcase Christian Dior and Pierre Balmain gowns in the grand foyer of the president's house. Intricately designed cocktail dresses and "at homes" from the sixties filled the solarium. Guests delighted in the accompanying text and photographs of the era.

For information about future Historic Costume Collection events, please send your name and address to Betty Alexander, Volunteer Coordinator, 701 West Pennsylvania Avenue, Urbana, IL 61801, or call (217)344-6256.



Family Relationships Laboratory Remodeled

The Family Relationships Laboratory in the Child Development Building now has a 1990s look and up-to-date research equipment. Remodeling funds were provided through the University of Illinois Research Board, the Illinois Agricultural Experiment Station, and the Home Economics/School of Human Resources and Family Studies Development Fund.

New furniture, back-lit windows, and two-way mirrors transformed a former kitchen area in the basement into a comfortable, attractive laboratory setting to observe and videotape children and parents. Two new color video cameras and VCR equipment were also purchased for research activities.

Laurie Kramer, assistant professor, Division of Human Development and Family Studies, was instrumental in design and development of the remodeled lab facility.

For Further Reference

General Publications

Education

How to Get Your Kid to Eat — But Not Too Much. Palo Alto, California: Bull Publishing.

Siblings: Love, Envy, and Understanding. J. Dunn and C. Kendrick. 1982. Cambridge, Massachusetts: Harvard University Press.

Family Financial Management

Financial Fitness for Newlyweds. Elizabeth S. Lewin. 1984. New York: Facts on File Publications.

"Five Crucial Financial Crossroads: Marriage, Birth of a Child, Mid-life, Retirement, Death of a Spouse, and What to Do When You Get There." Janet Bodnar. April 1990. *Money*. Pages 31–41.

How to Stop Fighting About Money and Make Some. Adriane G. Berg. 1988. New York: New Market Press.

Personal Finance. Thomas E. Garman and Raymond E. Forgue. 1988. Second edition. Boston: Houghton Mifflin.

Personal Financial Fitness: A Practical Guide to Improve the Health of Your Wealth. Allen Klosowski. 1989. Los Altos, California: Crisp Publications.

"Teaching Your Kids About Money." Mary Rowland. March 1990. *Money*. Pages 126–35.

Foods and Nutrition

Hypertension and Pregnancy. J.M. Sullivan. 1986. Chicago: Year Book Medical Publishers.

Nutrition, Pregnancy, and Early Infancy. C.L. Brown, ed. 1989. Baltimore: Williams & Wilkins.

Preventing Low Birthweight. National Institute of Medicine. 1988. Washington, D.C.: National Academy Press.

The Surgeon General's Report on Nutrition and Health. 1988. Washington, D.C.: Department of Health and Human Services. No. 88–50210.

University of Illinois Publications

More than 300 publications, videotapes, and slide sets by specialists at the University of Illinois are available through its Office of Agricultural Communications and Education, 69IR Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801. Write for your free copy of the *Resources Catalog*, which describes available materials and their prices, or to order publications. (For some publications, the first copy is free. Additional copies must be purchased.) A few titles relevant to this issue are listed below.

Consumer Issues

C1182, *Uses and Costs of Consumer Credit*, free ($.50)

C1194, *Consumer Credit: How You Are Protected*, free ($.50)

C1282, *Choosing a Long-Distance Telephone Company*, free ($.50)

C1284, *Telephone Purchase and Repair*, free ($.50)

C1294, *Shop Smart to Buy More for Less*, $1.75

NCR293, *Buying a Car? Be in the Driver's Seat*, $1.25

Economics and Farm Management

C1300, *Grower's Guide to Marketing Fruits, Vegetables, and Herbs in Illinois*, $5

C1304, *1989 65th Annual Summary of Illinois Farm Business Records*, $4

F1, *Illinois Farm Record Book* (two parts), $5.25

F2, *Farm Machinery Economic Decision Worksheets*, free ($1.50)

NCR2, *Income Tax Management for Farmers*, $2

NCR50, *Farm Business Arrangements: Which One for You?*, $3.25

NCR247, *A Computer for Your Farm: Some Things to Think About*, $2.25

NCR329, *Farm Personnel Management*, $3.25

Family Financial Management

C1218, *All About Us: Important Family Records*, $16 (also available as microcomputer software)

HG245, *Managing Your Personal Finances*, $2

Home and Family

AIB539, *Complete Guide to Home Canning* (USDA publication), $9

C817, *Plant Breeding as a Hobby*, free ($1)

C1125, *Beekeeping in the Midwest*, $5.50

C1206, *Life Insurance and Family Protection*, free ($1)

University of Illinois at Urbana-Champaign
Agricultural Experiment Station • D.A. Holt, Director
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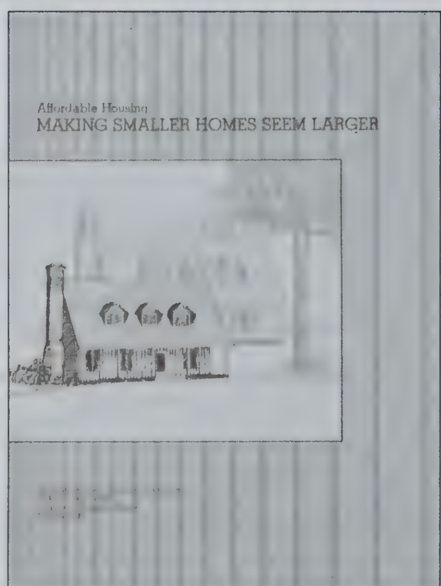


C1215, *Eating Right During Pregnancy,* $1.50

C1261, *Insuring Your Home,* free ($1)

HEP2, *Illinois Family Account Book,* $1.50

NCR259, *Selling Food Products: A Business from Your Home,* $.75

NCR282, *Parenting on Your Own Series* (14 titles), $3

Home, Lawn, and Garden

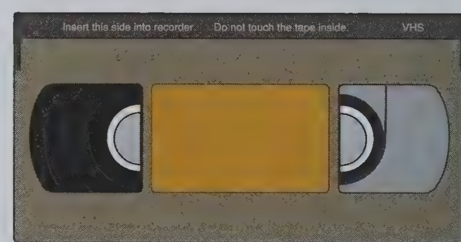
C1111, *Landscaping Your Home,* $7

C1239, *Affordable Housing: Making Small Homes Seem Larger,* free ($.50)

C1299, *Affordable Housing: Manufactured Homes,* $.50

C1302, *Affordable Housing: Home Remodeling Worksheet,* $1

Videotapes



The videos listed are available from the Film Center, University of Illinois, 1325 South Oak Street, Champaign, IL 61820. For information, call toll-free: (800)367–3456.

UIFC X00087, *Changing Directions...The Choice Is Yours* (opportunities for supplemental income)

UIFC X00097, *Empowering Single-Parent Families*

Et Cetera

The following publications are available from the Illinois Farm Electrification Council, University of Illinois, 360-F Agricultural Engineering Sciences Building, 1304 West Pennsylvania Avenue, Urbana, IL 61801.

Lighting for the Home. S. Isabell. 1986. No. 12.

Planning a New Kitchen. J.L. Wysocki. 1987. No. 13.

The following is available from the Small Homes Council–Building Research Council, University of Illinois, 1 East St. Mary's Road, Champaign, IL 61820:

Planning for Remodeling. J.L. Wysocki. 1988. C.8.0.

Illinois Rese

Agricultural Experiment Station
Fall/Winter 1990

Diversity in Agriculture

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 32, Numbers 3/4

The Cover

Wheat field along Route 78 south of Havana in the Illinois River valley.

"At a time unlike any in the past, we must envision the future."

Illinois Research

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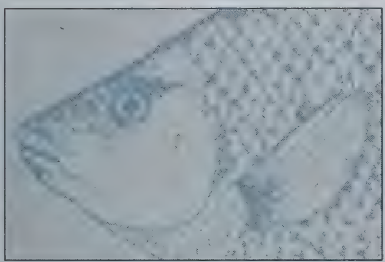
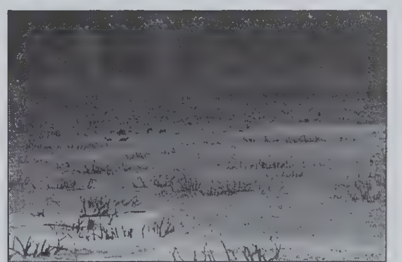
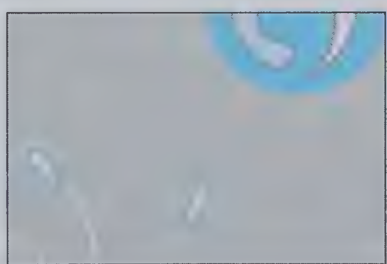
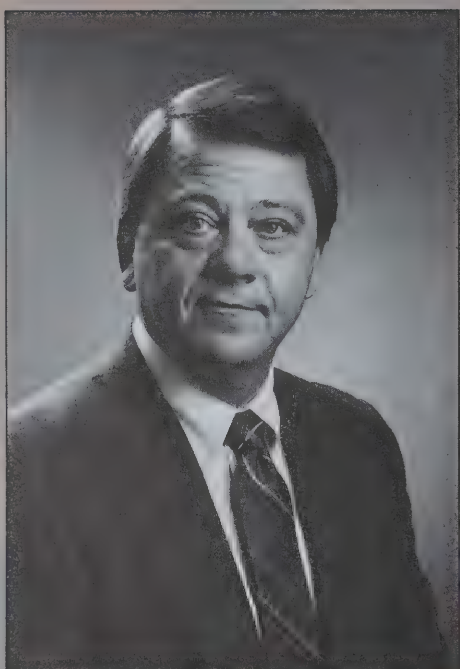






1990 – Directions – 2000

Diversity in Illinois Agriculture



Anton G. Endress

The hallmark of Illinois agriculture in this decade will be an accelerated diversification of agronomic, horticultural, and livestock products to accommodate the evolving needs and concerns of both consumers and producers.

Through its traditional research and development roles to enhance the production, processing, marketing, and use of agricultural products, the Illinois Agricultural Experiment Station has kindled significant changes in agriculture statewide. Today we have a greater variety of crop cultivars than ever before. Many of these new cultivars possess improved growth characteristics and yield performance, greater resistance to disease, or more tolerance to the vagaries of weather.

University of Illinois researchers have also helped improve varietal selection and cultural and management practices based on local climate and soil characteristics. And technological advances have spawned new uses for and new ways to process our traditional agricultural products. Thus, new marketing opportunities exist for these products.

Societal concerns will fuel even greater diversity and specialization in the future. The American public has a keen awareness that agriculture is an important part of everyday life and is essential to its long-term prosperity.

Recent concerns include the quality and safety of foods, the use of certain chemicals for weed and pest control, chemical contamination of water supplies and pollution of the air, erosion of valuable soils, climate change from global warming, and the loss of forests and extinction of organisms worldwide. These issues illustrate the public's recognition of the societal benefits to be gained from an agricultural enterprise attuned to a livable environment.

The evolving and expanding needs and desires of consumers dictate the development of different agronomic, horticultural, and livestock products. The public's expanding belief in the necessity of conservation and environmental stewardship

mandates the production of agricultural products in new ways as well. Producers will increasingly be challenged to provide what the consuming public wants.

Consumers are asking for more than just a greater variety of agricultural products. They want those products to be nutritious, of high quality, safe, and affordable. As a result, Illinois agriculture will see rapid change.

This issue of *Illinois Research* chronicles how diverse Illinois agriculture has become and illustrates the broad dimensions of future product diversification and specialization of both markets and growers.

Illinois agricultural research teams are at the forefront of advances in diversity and specialization. Breeders and biotechnologists continue to improve the traits of our crops and livestock to optimize their adaptation for specialty uses. Our agricultural commodities are being used in many new ways. High-value agricultural products and specialty crops are being studied and developed for targeted domestic and export markets. Production systems using fewer chemicals and less fertilizer are being investigated. Moreover, these advances will probably include the development and adoption of alternative farming practices.

As agriculture continues to diversify, production management will become more important. Producers will need to have a broader mix of knowledge and skills. And management practices will need to be of higher quality and intensity.

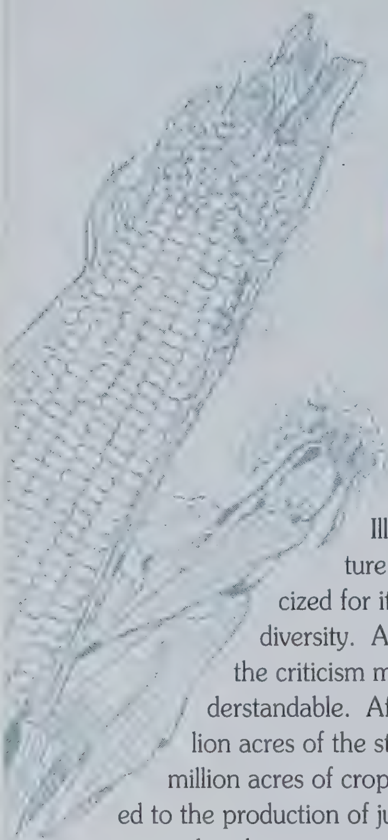
In the end, producers and consumers alike will have many more choices. Producers will be concerned with which commodities to produce, for which markets, and using which inputs. And consumers will choose between a greater variety of high-quality, safe, and nutritious agricultural products.

Anton G. Endress, professor and head, Department of Horticulture

■

Corn and Soybeans: Products, Perspectives, Innovations

David H. Baker



Illinois agriculture is often criticized for its lack of diversity. At first glance, the criticism may seem understandable. After all, 18 million acres of the state's 23 million acres of cropland are devoted to the production of just two crops: corn and soybeans.

But a closer look reveals where the diversity truly lies in regard to Illinois's two biggest crops. The state's endless miles of corn and soybeans eventually are used for a seemingly endless number of products — including meat, milk, and eggs — which find their way into virtually every U.S. household.

Annual corn production in the United States is close to 8 billion bushels; 1.8 billion bushels of soybeans are also produced each year. Illinois ranks first in soybean production and exports. As for corn, it ranks second to Iowa in production but first in the nation in exports.

Illinois corn and soybean production represents 18 percent of the U.S. total. Both corn and soybeans (as meal) are standard ingredients in diets for livestock, poultry, and companion animals.

Among the cereal grains, corn is highest in metabolizable energy. When combined with soybean meal, the high methionine and cystine in corn protein correct the deficiency of these important amino acids in soybeans. Likewise, the rich content of lysine and tryptophan in soybean meal corrects their deficiency in corn. The result is a near-perfect amino acid balance in what is commonly referred to as the corn-soy diet. No other pair of feed ingredients results in a better amino acid balance than corn and soybean meal combined in proper proportions.

Products from Corn

Of the total corn production in the United States, 57 percent is used for livestock feed; 27 percent is exported; and 16 percent is processed for food, seed, and industrial uses. Corn usage for the third category has doubled in the past ten years primarily because of increased demand for high-fructose corn syrup.

Per bushel processed, wet milling of corn produces 32.5 pounds of starch, 1.6 pounds of oil, 2.5 pounds of corn gluten meal, and 11.5 pounds of corn gluten feed (Table 1). Corn gluten meal, used principally in diets for poultry and companion animals, contains 60 percent protein. It is rich in methionine as well as carotenoid-xanthophyll pigments, the latter being important for skin pigmentation of poultry. Corn gluten feed, containing 22 percent protein, is used primarily in swine diets.

Almost 100 percent of the dry matter of corn is recovered in value-added products in the corn wet-milling process. Processing via wet milling is done to produce starch and products made from it. Thus, corn oil, corn gluten meal, and corn gluten feed can be considered byproducts of cornstarch production.

Starch is the starting material for high-fructose corn syrup, glucose, and dextrose. Of the starch that is marketed directly, half goes toward paper production and the other half toward food appli-

Table 1.
Annual Output of Food, Seed, and Industrial Products from Corn in the United States

Product	Estimated quantity	Estimated value
	millions of pounds	*millions of dollars*
High-fructose corn syrup	11,700	2,025
Seed	1,060	1,217
Dry-milled food products	9,020	966
Alcohol	5,530	866
Gluten feed	12,000	650
Glucose syrup	4,610	540
Starch	4,900	510
Gluten meal	2,400	375
Dextrose	1,130	335
Corn oil	1,530	320

Note: Data (1989) furnished by K.D. Brenner, director of public affairs, Corn Refiners Association, Washington, D.C.

cations. Biotechnology contributed to the development of high-fructose corn syrup as an important product for the food and soft-drink industries. The enzymes alpha-amylase and glucoamylase had been available for some time. These enzymes effectively convert starch to dextrose. A biotechnology breakthrough led to a fermentation process for making glucoisomerase, the enzyme that converts dextrose to fructose. High-fructose corn syrup has a "clean" taste. In chilled solutions, the product, containing 90 percent fructose, is about 1.35 times sweeter than conventional sugar (sucrose). The soft-drink industry uses 70 percent of all high-fructose corn syrup produced.

About 60 percent of the alcohol produced from corn (through starch fermentation) comes from the wet-milling industry. The remaining 40 percent comes from dry milling. A bushel of corn will yield 2.5 gallons of ethanol. Most of the ethanol produced from corn is used as a gasoline additive. The dry-milling industry produces corn flours and other products used principally for constructing corn-based foods such as breakfast cereals and corn chips.

New Research with Corn

University of Illinois scientists have been active for many years in efforts to develop corn varieties high in oil or protein. Conventional breeding procedures to produce high-protein corn result in a protein of inferior quality (that is, low in lysine and tryptophan). Therefore, novel procedures have been developed to generate varieties not only high in protein but also high in lysine, tryptophan, and methionine. These varieties have the potential for use in both animal feeds and human foods.

A relatively new product derived from cornstarch is polydextrose, a complex carbohydrate containing only one kilocalorie per gram, about one-fourth the caloric value of starch or dextrose. This product is being marketed to the food industry for use in reduced-calorie candies, puddings, and other products. Several companies are attempting to develop similar products from cornstarch. The Animal Sciences Department at the University developed both the in vitro (chemical) and in vivo (animal) screening procedures that are used to assess caloric content.

Products from Soybeans

During the September 1989 to September 1990 marketing year, 1,783 million bushels of U.S. soybeans were consumed. A total of 62.5 percent was crushed for oil and soybean meal; 32.3 percent was exported; and 5.2 percent was considered "seed, feed, and residual." Of the 66.9 billion pounds of soybeans crushed, 12.4 billion pounds of oil and 52.8 billion pounds of meal resulted. Eleven percent of the oil and 19 percent of the meal were exported. Domestic use of soybean meal consists of 46 percent for poultry, 32 percent for swine, 9 percent for beef cattle, 9 percent for dairy cattle, and 4 percent for other species. Data in Table 2 provide a distribution of domestically used soybean oil.

The oil extracted from soybeans represents 36 percent of the total value of the crop. Upon solvent extraction, one bushel of soybeans yields 11.1 pounds of oil. Close to 98 percent of the oil is manufactured into food products.

A small percentage of crushed soybeans is converted into edible soybean flours and concentrates for humans. An estimated 750 million pounds of these materials were produced in 1985. And markets for these products are expanding, particularly for alcohol-extracted material. Alcohol extraction removes most of the oligosaccharides (complex carbohydrates) from soybeans, thereby minimizing flatulence problems associated with oligosaccharide consumption. The University's Department of Food Science has been a leader in research designed to develop palatable and nutritious food products from not only soybeans but also corn.

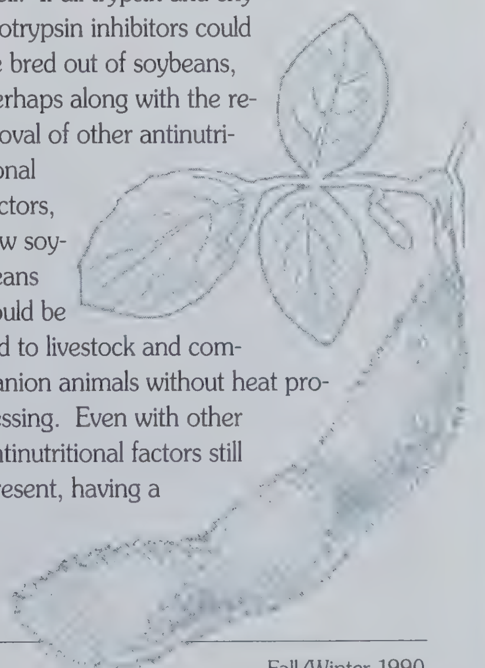
Table 2.
Soybean Oil Usage in the United States

Product	Estimated quantity
	millions of pounds
Cooking and salad oils	5,068
Shortening	3,854
Margarine	1,675
Other foodstuffs	139
Resins and plastics	97
Soaps and miscellaneous	82
Paint and varnish	55
Fatty acids	30
Total	11,000

Note: Data are estimates for the 1989–1990 marketing year based on information presented in *Oil Crops Situation and Outlook* (October 1989), USDA, ERS; and *Soya Bluebook*, 1986.

New Research with Soybeans

Agronomists at the University have developed a soybean variety devoid of the Kunitz trypsin inhibitor, a protease enzyme inhibitor that lowers protein digestion in monogastric animals such as pigs, chickens, and humans. Work is continuing toward the development of varieties lacking other antinutritional factors as well. If all trypsin and chymotrypsin inhibitors could be bred out of soybeans, perhaps along with the removal of other antinutritional factors, raw soybeans could be fed to livestock and companion animals without heat processing. Even with other antinutritional factors still present, having a



Kunitz-free soybean means that less heat processing will be required to deactivate the non-Kunitz protease inhibitors. This energy-saving phenomenon is extremely important to the soy processing industry.

Research with pigs and chickens at the University has led to an *in vitro* test in which soybean protein is dissolved in 0.2 percent potassium hydroxide (KOH) to determine whether soybean meal has been overheated. The KOH solubility test has considerable potential for use in the food and feed industries as a quick and simple *in vitro* test for predicting *in vivo* protein quality of soybean meals and flours.

Researchers are evaluating soybean oil's potential as a replacement for diesel fuel and as a raw material for printing ink. As a food-grade product, soybean oil contains about 12 percent saturated fat. Its unsaturated fat consists of 10 percent triglyceride-containing omega-3 fatty acids. These fatty acids are among the important components of marine and canola oils, thought to prevent atherosclerosis in humans. By comparison, only 1 percent of the fatty acids in corn oil are omega-3. Nonetheless, both corn oil and soybean oil are rich in polyunsaturated fatty acids, which are believed to help prevent high blood cholesterol in humans.

Research at the University has shown that feeding soybean oil to pigs increases the omega-3 fatty acid content fourfold in both loin muscle and subcutaneous fat. Although this increase is dramatic, it is important to note that even in pigs fed soybean oil, the omega-3 fatty acid content represents only about 0.5 percent of the total fatty acids in pork loin and about 1.2 percent of the total in subcutaneous fat.

Ethanol can be used as an alternative to petroleum-based fuel.

Recent research at Iowa State University has resulted in a soybean variety with only 6.2 percent saturated fat. More importantly, the concentration of palmitic acid, a saturated fatty acid, is reduced from 10 percent in standard soy oil to only 3.5 percent, about the same as in canola oil. Palmitic acid has been shown to elevate serum cholesterol. Because canola oil is low in saturated fat and high in omega-3 fatty acids, it has received endorsements from health associations such as the American College of Nutrition. As a result, canola oil has cut into the market for U.S. soybean oil. If the genes that lower palmitic acid concentration can be bred into existing high-yielding varieties, significant new markets could develop for low–palmitic-acid soybean oil.

Looking Toward the Future

Eventually, the reduced supply and increased price of petroleum will open new opportunities for manufacturing fuels and industrial chemicals from corn using environmentally sound methods. Petrochemicals now are used to produce 9.6 billion pounds of ethylene and 6.6 billion pounds of propylene each year for plastics manufacturing. Researchers, with the help of biotechnology, have developed methods for producing a multitude of industrial chemicals from corn. Although current methods involve fermentation of cornstarch to produce ethylene and propylene, University scientists are evaluating fiber-digesting bacterial processes to convert fibrous waste materials such as corn stalks and corn cobs into useful organic chemicals. They are also searching for cost-effective ways to make calcium magnesium acetate (CMA) from corn.

CMA has the same ice-melting properties as calcium chloride, which is used to keep roads and bridges from becoming iced over. Unlike calcium chloride, however, CMA is biodegradable and does not cause motor vehicles to rust.

Corn and soybeans, in contrast to petroleum, are renewable resources. Both products have a brilliant and still unrealized future. Farmers and food processors in Illinois are ideally situated to take full advantage of what some have called "the best location in the world to produce *both* corn and soybeans."

David H. Baker, University scholar and professor of nutrition, Department of Animal Sciences and Division of Nutritional Sciences

■

The Economics of Diversity

Steven T. Sonka and Sarahelen Thompson

The overall food and agribusiness industry in Illinois constitutes a large and diverse component of the state's economy. Food processing alone generates more than $19 billion annually. Indeed, all sectors of the industry, including farm equipment manufacturing, farm input suppliers, grain elevators and merchandisers, and the associated agricultural services, contribute to the economic well-being of the state.

But in spite of the variety found in its overall food and agribusiness sector, Illinois has seen a decline in the diversity of its production agriculture. As the dynamics of agricultural economics have changed over the past thirty years, so have the production practices of farmers.

Illinois Farms: Then and Now

Agricultural production in Illinois is considerably different today than it was just a few decades ago. One example of the changes that have occurred can be seen in the mix of crops produced. Figure 1 compares the proportion of acreage devoted to five major crops — corn, oats, wheat, soybeans, and hay — in Illinois for the periods of 1957–59 and 1985–87.

Although the total acreage of crops in the 1950s as compared to the 1980s is fairly consistent, the mix of crops differs dramatically. The major change is the drastic increase in acreage devoted to soybeans. Over four million more acres were devoted to the soybean crop in the 1980s than were planted to soybeans just thirty years previously. Clearly the "soybean miracle," in terms of both production technology improvements and growth in demand, has had a major impact in Illinois.

Those four million additional acres of soybeans had to come from other uses. Part of the acreage came from oats and hay, whose total acreage has dropped sharply since the 1950s (Figure 1). Another interesting feature shown in Figure 1 is the different levels of diversification in the two periods. In the 1950s, crop acreage was more evenly distributed between several crops. In the 1980s, acreage was dominated by corn and soybeans.

In addition to looking at crops and state acreages, it is useful to consider diversity in terms of agricultural production on individual farms. (Keep in mind that not only crops but also livestock are important components of Illinois agriculture.) Three snapshots of livestock agriculture in Illinois are shown in Figure 2. As can be seen, the number of farms reporting production of the three main types of Illinois livestock — beef cattle, dairy cows, and swine — decreased over the past thirty years.

Total livestock numbers have also fallen, but not to the extent that the number of farms producing livestock has declined. The number of beef cows declined by 57 percent between 1959 and 1987. Milk cow numbers fell by 66 percent during the same period, and hogs and pigs fell by 32 percent. Increasing specialization of production on individual farms explains why the number of farms has declined more sharply than has the number of livestock produced.

Not surprisingly, the massive decline in the number of farms producing livestock during the 1960s and 1970s coincided with a major expansion in soybean acreage and a decline of oat and hay acreage during the same period. The trend toward specialization continued throughout the 1980s.

But why did the trends away from diversity and toward specialization occur in the first place? And will they continue?

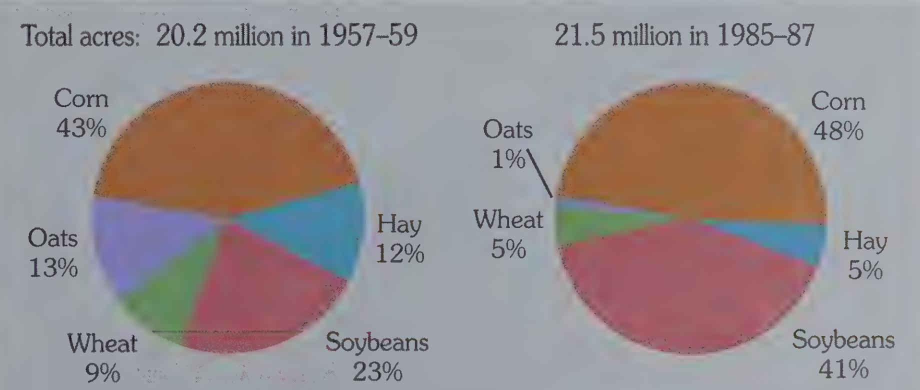


Figure 1. Major crops in Illinois: the 1950s versus the 1980s.

Economic Forces Affecting Diversification

For many years, agricultural economists have been analyzing the forces that affect diversification. Their analyses have identified numerous factors influencing diversification. Some factors encourage it and others do not.

Three of the most influential economic forces in Illinois are comparative advantage, scale economies, and risk management.

Comparative advantage. This concept holds that people in two regions will be better off if, rather than both undertaking all activities, each region specializes in the activity it does best and then trades with the other region. The activities that each region should engage in are those for which it has the greatest "comparative advantage."

Let's consider an example. Beef cows can be raised in both Illinois and New Mexico. In Illinois a cow and calf might require an acre of grazing land. In New Mexico more than ten acres would be needed for that same cow and calf. Yet beef cattle production is relatively much more important in New Mexico than in Illinois.

The reason for this seeming paradox is that Illinois enjoys a comparative advantage in the production of other commodities, such as corn and soybeans. Therefore it is more economical for each of the states to specialize in production and then trade with the other state for agricultural commodities and products that it does not produce.

The idea of comparative advantage is just as relevant for individual farms as it is for regions and states. For example, one producer may have resources and skills best suited to producing soybeans and corn. Another producer may have interests and abilities better suited for swine production. Therefore, if these producers maximize comparative advantage, they will tend to become more specialized.

Technology plays a key role in determining comparative advantage. Clearly the use of agricultural chemicals to control pests reduced the need for rotations, fueling the types of acreage changes shown in Figure 1. And advances in confinement livestock production facilitated the changes shown in Figure 2.

Scale economies. This term refers to the extent to which production costs decline as output increases. These cost savings, or economies, are a major cause of specialization. Scale economies often exist because of large fixed costs for machinery and equipment that decline on a per-unit basis as output increases. Where substantial scale economies exist, firms will tend to specialize to produce enough output to take advantage of those economies.

As production agriculture has become more scientific, managerial attention and capability have been added to the list of factors associated with scale economies. It takes time to remain current with all the changes and advances associated with today's production agriculture. The producer trying to keep up to date on four or five commodities has a much more difficult task than does the producer concentrating on just one or two.

Risk management. A negative feature of specialization is that the producer is more vulnerable to the sharp swings of price and production that characterize farming. The completely specialized producer has put all the firm's eggs in one basket. If incomes are low in that basket, no other enterprise exists to offset the decline.

However, today's producer has a number of means to counteract this financial risk that may not be apparent by just considering the number of crops and livestock enterprises that exist. Examples include government farm programs, off-farm income, and financial and marketing instruments.

Earlier we looked at acreage in five major crops in Illinois. One major "crop" not considered was acreage idled because of government farm income support programs. These programs used one to three million acres in the state between 1987 and 1989. By providing income stability, income support programs are felt by many to have contributed to the specialization of crop and livestock production.

Off-farm income is another means of diversification. In 1987, 22 percent of the nearly 63,000 commercial farms in Illinois (those with sales in excess of $10,000) reported more than 200 days of off-farm employment. Clearly the presence of this additional flow of revenues

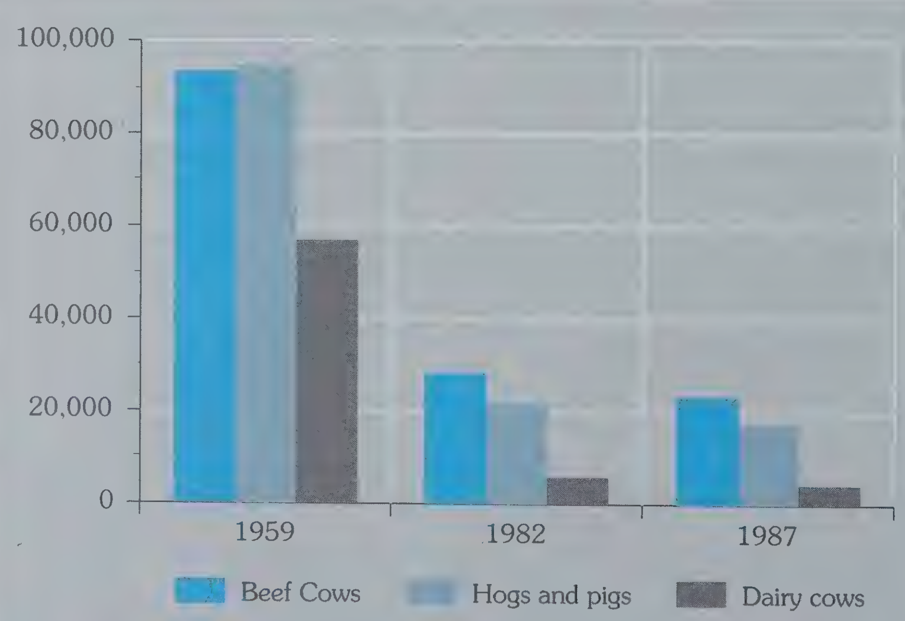


Figure 2. Farms with livestock in Illinois: 1959, 1982, and 1987.

Thirty years ago, many farmers raised livestock in addition to growing field crops (above). Since then, a trend toward specialization has changed the look of Illinois agriculture (below).

could affect the producer's need to diversify to stabilize agricultural receipts. Additional nonproduction instruments for stabilizing income flows include hail and all-risk insurance, forward contracting, hedging with futures contracts, and using options on futures contracts.

Is Diversity in Our Future?

During the late 1950s it is not likely that anyone would have correctly foretold all the changes we have witnessed in the last thirty years of Illinois agriculture. Our crystal ball is not necessarily any brighter today than it was then. Therefore, an attempt to predict specific changes to occur in the future would be feeble at best.

There are, however, three major forces that are likely to affect the state's agricultural diversification (or lack thereof) during the 1990s. They are environmental concerns, high-value agricultural products, and government intervention.

Environmental concerns. The technologies that facilitated the growth of row-crop agriculture in Illinois are now being blamed for creating chemical residues in ground water and soil erosion.

Societal responses to these environmental concerns may affect the comparative advantage of alternative commodities and production systems. These responses most likely will include the development and adoption of alternative farming practices to increase diversity on individual farms and protect the state's natural resources. For further discussion of this topic, see the fall/winter 1989 issue of *Illinois Research*, which focused on sustainable agriculture.

High-value agricultural products. Biotechnology, changing consumer preferences for food, and rising consumer incomes have increased the potential for economic production of high-value products. Examples include specialty crops such as baby vegetables and shiitake mushrooms, as well as alternative crops such as canola and specific soybean varieties for targeted export markets.

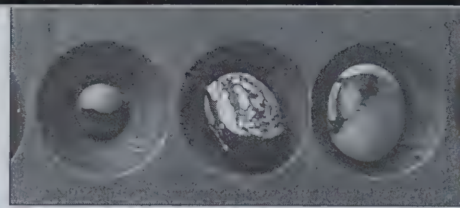
Although an increase in high-value agricultural products could enhance the diversity of Illinois agriculture, it could also present a number of interesting problems. Marketing challenges may be difficult to overcome in many of these situations. For further discussion, see the spring/summer 1989 issue of *Illinois Research* ("The Risky Business of Thin Markets," by Sarahelen Thompson).

Government intervention. Probably the single most contentious international trade issue over the last five years has been the agricultural support policies of the major world traders. The success of the current General Agreement on Tariffs and Trade (GATT) negotiations is widely believed to hinge on an agreement on agricultural protection being reached among the United States, the European Economic Community, Japan, and the other major agricultural exporting nations.

If agreements to reduce trade-distorting subsidies are reached, major changes in government support policies will occur. Coupled with concerns over the nation's budget deficit, these changes could reduce direct government subsidies to agriculture.

Assuming that government support payments have contributed to agricultural specialization, it is logical to expect reductions of those payments to lead to reduced pressures for specialization.

Steven T. Sonka, professor of agricultural economics, and Sarahelen Thompson, associate professor of agricultural economics



Differentiation in Grain Commodity Markets

Marvin R. Paulsen

As we explore diversity in the agricultural commodity markets of Illinois, it becomes obvious that just as all grain varieties are not alike in yield potential, they are also not alike in end-use value. Despite this fact, however, U.S. grading standards traditionally have tended to promote the idea that "all grain is alike."

Grade distinctions traditionally have been determined by factors relating to the condition of the grain at the time of its sale. Such factors may include percentages of broken material; mold-, insect-, or heat-damaged kernels; and test weight. But intrinsic factors such as chemical composition and kernel hardness also contribute to the grain's value. A system for distinguishing grades based on these intrinsic characteristics could provide for greater differentiation in grain markets.

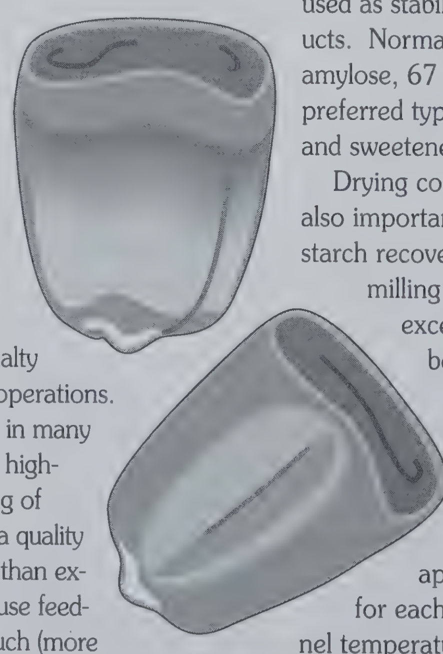
Corn Quality Characteristics

Other than seed production, there are four primary uses for corn. More than 75 percent of U.S. corn goes to feeding livestock and poultry both here and abroad. Another 13 percent to 15 percent is used for wet milling. Dry milling and alkaline processing combined use about 2 percent to 3 percent. Assuming moisture content and mold-damage levels are sufficiently low, corn produced for each of these purposes has specific intrinsic factors that help define its value as a commodity.

For livestock and poultry feeding, chemical constituent contents are important. Feed rations are often tailored to the protein content available in a corn lot, resulting in cost savings. Opaque-2 corn is desirable for feeding because of its high content of lysine and tryptophan, two important amino acids. Because of its reduced zein protein, however, opaque-2 corn has predominantly soft endosperm, making it easy to break.

Swine benefit from diets of high-lysine and high-oil corn. High-lysine corn improves feed gain for nursery pigs. High-oil corn has been used in nursery and lactation swine rations to provide additional energy and reduced dust.

Improvements in technology, such as near-infrared reflectance (NIR) and near-infrared transmittance (NIT) units, have made it faster and easier to analyze corn samples. As this new technology becomes more widely available to provide rapid protein, oil, moisture, starch, and fiber analysis, markets will become more specialized. This will lead to more requests for specialty corn for feeding operations.



Timely harvest in many cases necessitates high-temperature drying of corn, resulting in a quality level that is lower than expected. But because feeding requires so much (more than three-quarters) of our annual corn production and high-temperature–dried grain is suitable for livestock, there is always a market for such grain.

For wet milling, corn is steeped in a sulfur-dioxide solution for twenty to thirty-eight hours at 122° to 131°F. This process separates out the germs and fiber, leaving a starch-gluten slurry. The purpose is to obtain food starch, or to produce fructose or ethyl alcohol.

The variety of corn affects the type of starch obtained. Waxy corn (99 percent amylopectin) produces a high-viscosity starch used for food stabilizers and thickeners. High-amylose corn (50 percent amylopectin, 50 percent amylose) produces a starch that resists swelling, withstands high-temperature cooking, and forms strong gels that are used as stabilizers in confectionery products. Normal dent corn (33 percent amylose, 67 percent amylopectin) is the preferred type for producing food starch and sweeteners.

Drying corn at lower temperatures is also important for obtaining good starch recovery percentages in wet milling. If kernel temperatures exceed 140°F, the protein may be denatured, making the separation of starch from protein gluten more difficult, leading to reduced starch yield in the wet milling operation. As an approximate rule of thumb, for each 10°F increment that kernel temperature increases over 140°F,

starch yield decreases by one percentage point.

Excellent corn for wet milling can be obtained using natural-air or low-temperature drying methods. For increased drying speed, combination drying (where the moisture below 20 percent is removed with low heat) can be used. For higher drying capacity, concurrent flow dryers with tempering can be used if kernel temperatures do not exceed 140°F.

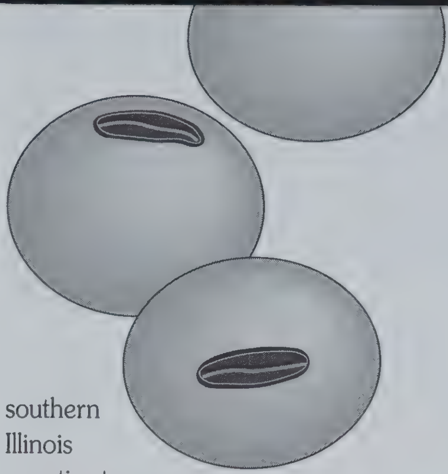
For dry milling, kernel hardness is most important. Hardness is defined as the amount of vitreous endosperm relative to the amount of floury endosperm. The harder the corn, the higher the ratio of vitreous to floury endosperm. The purpose of dry milling is to remove the germ and to obtain large pieces of vitreous endosperm, which make up the large flaking grits. These large grits are used to make corn flakes. Thus, hard-endosperm corn results in higher yields of large corn flakes than soft-endosperm corn. For corn used in snack foods and alkaline processing, hard endosperm is again desirable.

Corn hardness is determined primarily by variety. Under dry growing conditions, however, endosperm tends to become harder than it would were ample moisture available. Generally, as corn hardness increases, kernel density increases, kernels exhibit greater resistance to grinding, and ground particle sizes are larger than for soft corn.

Soybean Quality Characteristics

Soybeans are primarily used for processing into oil and meal. The percentages of oil and protein in soybeans used for domestic crushing are usually not measured. In September 1989, however, the Federal Grain Inspection Service (FGIS) started providing protein and oil measurements as official criteria if requested.

Soybeans vary in protein and oil both by variety and growing location. In 1989 the Identity Preserved Grain Laboratory in Urbana, Illinois, found protein to vary significantly — from 35.8 percent in



southern Illinois counties to 33.5 percent (at 13 percent moisture) in east-central counties. Percentages of oil ranged from 19.9 percent (at 13 percent moisture) in east-central counties to a low of 18.6 percent in southern counties.

For soybeans purchased for processing, an estimated process value (EPV) was calculated. EPV provides a prediction of the value of a bushel of soybeans based on its protein and oil composition, normal processing conversions, and the current price of crude soybean oil and 44-percent soybean meal. In this example, EPV ranged from $6.59 per bushel in southern Illinois to $6.41 in eastern Illinois. These values were based on 19.3 cents per pound for crude soybean oil and $183.10 per ton for soybean meal. The soybean variety greatly affects EPV.

A soybean processor would prefer to know EPV. But a producer would prefer to know the estimated process value per acre (EPVA), which takes into account the soybean yield per acre. There is no incentive for a farmer to plant a soybean variety with an excellent EPV value unless it also has a high EPVA value.

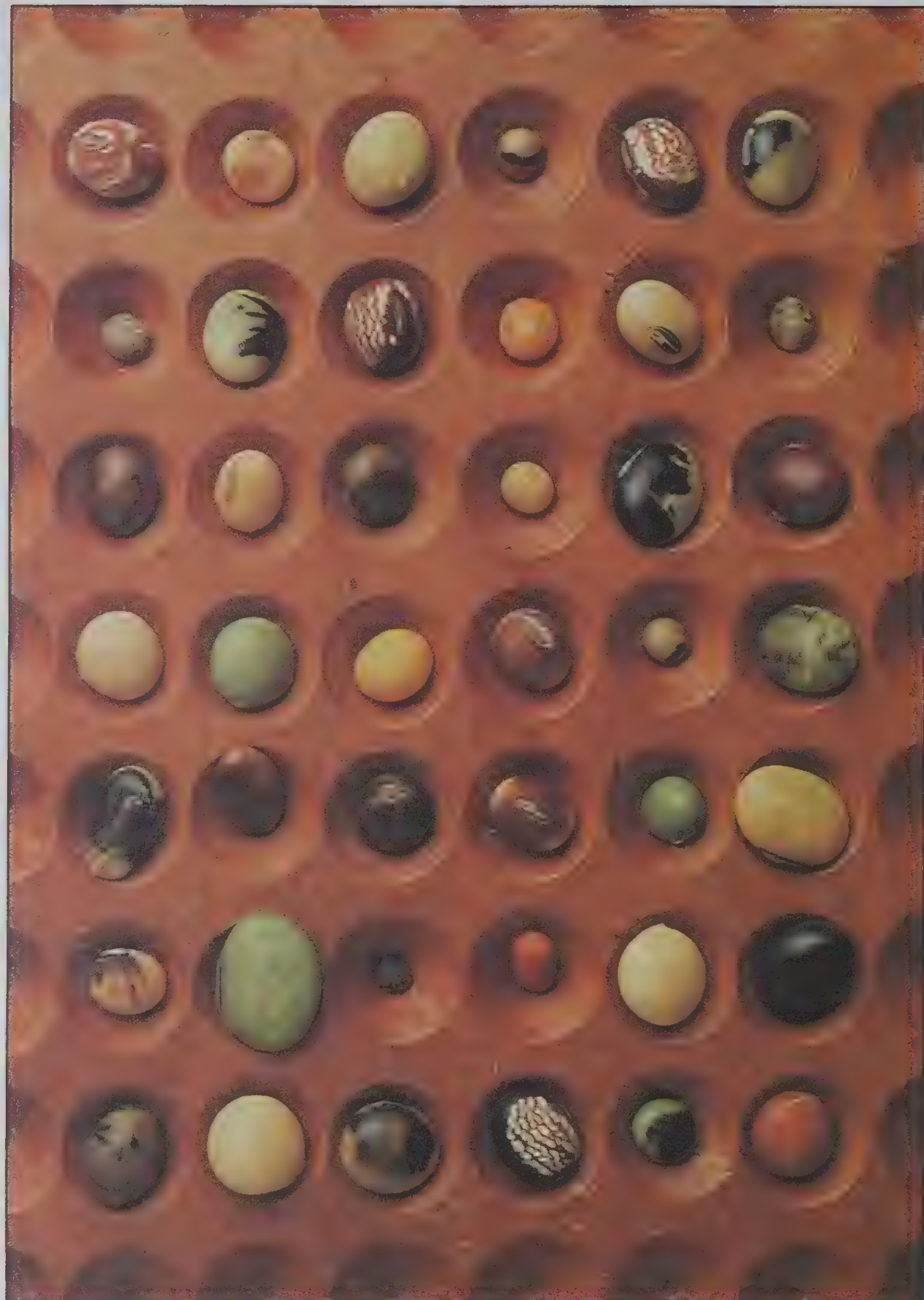
In a comparison study of Group III soybeans in thirty-inch rows grown at Urbana in 1989, the Identity Preserved Grain Laboratory found the EPVA to vary from a high of $489 per acre to a low of $289 per acre. The variation was due primarily to variety selection. With sufficient market incentives, it is possible to select varieties with relatively high EPVA *and* EPV values.

The American Soybean Association (ASA) has recommended that new soybean varieties have protein and oil percentages that sum to 62 when expressed at 0 percent moisture. For example, the east-central Illinois averages of protein at 33.5 percent at 13 percent moisture would be 38.51 percent at 0 percent moisture. The averages of protein at 19.9 percent at 13 percent moisture would be 22.87 percent at 0 percent moisture. These numbers sum to 61.38. This average value is below the recommended 62, yet many of the *individual* varieties had sums greater than 62.

The relative value of protein versus oil continually shifts with meal and oil market prices. The position ASA has taken is that selection should be made for high protein, citing that a 1 percent increase in protein reduces oil by 0.25 percent, whereas a 1 percent increase in oil results in an average decrease of 1.3 percent in protein. Further, the higher the protein the lower the fiber, and a more favorable amino acid balance results.

One of the major changes creating differentiation in soybean markets has been the introduction of the new Kunitz soybean, recently developed at the University of Illinois. The Kunitz variety, which can be fed to livestock without processing, could provide an alternative protein source in regions where soybean meal is not readily available. The Kunitz soybean also could lead to cost savings in processing by reducing the need for heat-roasting. (See related article on page 4 for more on the Kunitz soybean.)

Another important market for soybeans is the tofu industry. For this use, important characteristics are high protein and a light-colored hilum. A black hilum causes the tofu product to lose its traditional creamy white color. Yield of tofu increases as the percentage of protein recovered during processing increases. Desirable tofu soybeans should have a moisture content of 13 percent or less; a protein content of 36 percent or more at 13 percent moisture; a hilum color of brown, buff, clear, or imperfect black; medium-sized seed (2,300 to 2,500 seeds per pound) and U.S. No. 1 or better for foreign material, splits, and



Soybeans come in many shapes and sizes.

damage factors. These criteria were established by the Identity Preserved Grain Laboratory.

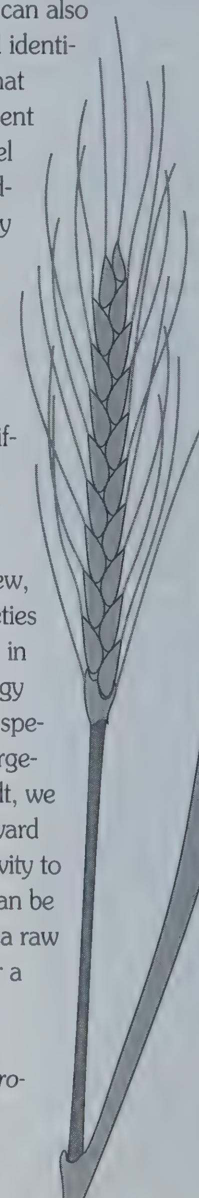
Wheat Quality Characteristics

Traditionally wheat has been ahead of corn and soybeans in the tests performed relative to end use. Most wheat is milled to produce flour for human consumption. There are primarily five classes of wheat grown in the United States. Hard red spring wheat and hard red winter wheat are preferable for use in yeast breads and hard rolls. Durum wheat is used for macaroni and spaghetti. Soft red winter wheat, grown in the eastern half of the nation, is used for making cakes, pastries, flatbreads, and crackers. Soft white wheat — used for noodles, cakes, pastries, flatbreads, and crackers — is grown mainly in the Northwest, New York, and Michigan.

In the past, only the class of wheat needed to be known to select for best end use. Wheat classes were determined by visual inspection. But over the years, plant breeders have crossed soft red wheat with hard red wheat to improve disease resistance and yields. The resulting crosses have the visual characteristics of soft wheat yet the functional characteristics of hard red wheat.

The mixed characteristics of new wheat varieties can lead to misidentification of wheat types and eventual problems at the processing plant. For instance, a wheat mill designed for soft wheat cannot produce the expected flour if hard wheat is mixed in with the soft wheat.

Actual wheat varieties can be identified by electrophoresis to analyze gliadin, a major protein contained in the wheat gluten. High-performance liquid chromatography (HPLC) can also provide good varietal identification. It is likely that tests for protein content and quality and kernel hardness will be needed to correctly classify wheat for class and end use.



The grain commodity markets in Illinois are experiencing more and more differentiation. These changes are fueled by consumer needs that continue to require new, specialized grain varieties and by improvements in the research technology used to identify these specialized grains on a large-scale basis. As a result, we are seeing a trend toward greater market sensitivity to intrinsic factors that can be used to better predict a raw commodity's value for a particular end use.

Marvin R. Paulsen, professor of agricultural engineering

How Sweet It Is

J.W. Courter and Floyd S. Ingersoll

Ninety-eight-year-old Martin Miller of Indianapolis has been growing Xtra-Sweet hybrids for 25 years. He calls them "the very best sweet corn available."

Sweet corn keeps getting sweeter. Thanks to nearly thirty years of plant breeding and hybrid development, today's consumer can purchase tasty hybrids up to four times as sweet as "standard" sweet corn.

Researchers have identified a number of different genes that increase sugar levels above that found in standard sweet corn. New varieties possessing these genes may contain as much as 12 percent sugar by fresh weight. They may also have unique eating, freezing, or canning qualities.

For many years, the only choice available was standard sweet corn, a variety containing about 6 percent sugar by fresh weight. Plant breeders called the variety "sugary" by virtue of its *su* gene, which causes sugars, rather than starch, to be stored in the kernels.

Considering Illinois's distinction as a top corn producer (third among states in production of corn for processing and tenth in production of fresh-market corn), it is no surprise that the University of Illinois has led the effort to improve the quality and variety of sweet corn. Indeed, the two dominant types of high-sugar sweet corn on the market today, the *shrunken-2* (*sh_2*) and *sugary enhancer* (*se*), both were developed from basic research at the University.

In the early 1950s, John R. Laughnan of the University's Department of Botany discovered the high-sugar *shrunken-2* gene. At that time, his discovery was considered a novelty. The first commercial hybrid, Illini Super Sweet, was introduced in 1960 by Illinois Seed Producers Association, Inc. (now Illinois Foundation Seeds, Inc.). This was followed by an improved hybrid named Illini Xtra-Sweet and by Early Xtra-Sweet, an All-America Selections winner in 1971. These hybrids, which tend to be less creamy and more crispy in texture than standard sugary sweet corn, have become popular worldwide. For example, commercial *shrunken-2* hybrids have captured more than 75 percent of the market in Japan and 95 percent of the market in Taiwan.

The *sugary-enhancer* gene was discovered in 1967 by A.M. Rhodes in the Department of Horticulture. Hybrids containing this gene vary in kind and amount of sugar as well as eating quality. Some customers prefer the creamy texture and flavor inherent to these hybrids.

Today, a large number of *shrunken-2* and *sugary enhancer* hybrids are suitable for planting in Illinois. These new hybrids are up to four times sweeter than standard sweet corn forty-eight hours after harvest. Researchers are also working to improve germination, plant vigor, and disease resistance of high-sugar corn.

The texture, flavor, and color of new sweet corn cultivars vary with the genetic type. Today's consumer can find subtle texture and flavor differences in yellow, white, and bicolor (mixed yellow and white kernels) sweet corn.

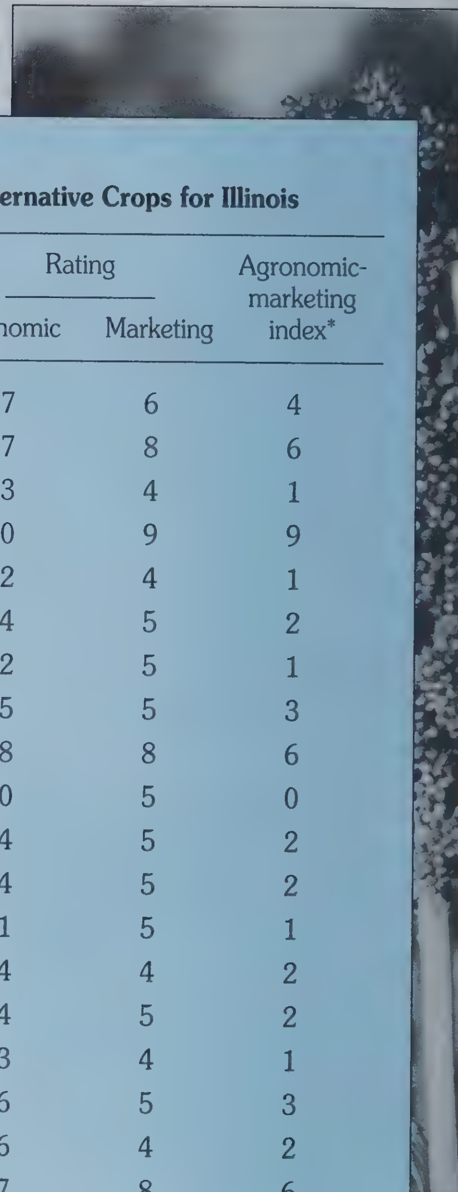
Growers must "know their corn genes" before planting fields or gardens. Cross-pollination of unlike genotypes may result in undesirable, starchy kernels.

Americans simply love corn. Each year we gobble down more than eleven billion ears of fresh or home-processed sweet corn. And consumption should continue to grow as hybrids are developed with a range in sweetness, distinctive flavors and textures, and improved shipping and handling characteristics.

J.W. Courter, professor of horticulture and Extension specialist, Dixon Springs Agricultural Center, Simpson; and Floyd S. Ingersoll, executive vice president, Illinois Foundation Seeds, Champaign

A World of Opportunities Is Cropping Up

Emerson Nafziger



Although corn and soybeans would be hard to replace for most feed and export markets, many alternative crops have a strong potential to succeed in other markets.

Corn and soybeans provide a good balance of protein and calories (carbohydrates plus oil) for the animal-feed and export markets. Given the tremendous genetic improvement of these crops and the comparative advantage they enjoy in Illinois, it would be hard to find a new crop that would provide either protein or calories more efficiently (that is, more cheaply). Instead, it may be more appropriate to look for a crop that will be used for new products, for which prices may be higher.

Before deciding to grow a new crop, producers need to consider not only its agronomic adaptability but also its marketing potential. The latter is largely determined by the crop's eventual uses. The success of a new crop depends on good yields of a marketable product.

Table 1 lists a number of crops that are grown somewhere in the world and for which markets, or market potential, do exist. Each crop's most common uses are given, along with the author's ratings for the crop's agronomic and marketing potential in Illinois. The agronomic rating takes into account not only climatic adaptation and yield potential but also expected yield stability. Likewise, the marketing rating incorporates crop use, production in other countries, and the value of the end products. Finally, the agronomic and marketing ratings are combined to give an index of potential for the crop to succeed in Illinois.

There are, of course, many other crops grown in the world besides those

Table 1.
Agronomic and Marketing Potential of Alternative Crops for Illinois

Crop	Use	Rating		Agronomic-marketing index*
		Agronomic	Marketing	
Amaranth	Food	7	6	4
Canola	Oil, meal	7	8	6
Chickpea	Food	3	4	1
Corn	Feed	10	9	9
Cotton	Fiber	2	4	1
Crambe	Industrial oil	4	5	2
Cuphea	Manufacturing	2	5	1
Dry beans	Food	5	5	3
Grain sorghum	Feed	8	8	6
Jojoba	Wax	0	5	0
Kenaf	Woody fiber	4	5	2
Lentil	Food	4	5	2
Lesquerella	Industrial oil	1	5	1
Lupins	Feed	4	4	2
Meadowfoam	Industrial oil	4	5	2
Milkweed	Down, organics	3	4	1
Millet	Feed	6	5	3
Mungbean	Food	6	4	2
Oats	Food, feed	7	8	6
Palm	Oil	0	7	0
Pea	Food	4	6	2
Peanut	Oil, food	2	3	1
Quinoa	Food	1	6	1
Sesame	Oil	4	5	2
Soybean	Oil, meal	9	10	9
Stokes aster	Manufacturing	4	5	2
Sunflower	Oil	5	6	3
Tobacco	Smoking	3	3	1
Wheat	Food	8	9	7

Note: Agronomic and marketing ratings are based on a 0–10 scale, 0 being the lowest rating possible.

* Derived by multiplying the agronomic and marketing ratings, then dividing by 10 and rounding off.

Drought-tolerant grain sorghum can be fed or marketed in Illinois but does not compete well with corn on better soils.

listed in the table. The recent surge of interest in ethnic foods may create lucrative local markets for some of these crops. Producers should keep in mind, however, that agronomic characteristics and growing-season requirements for some alternative crops may be largely unknown. And the risk of market saturation and competition from low-priced imports may affect the marketing success of such crops. For these reasons, some new crops may be grown on fairly small acreage to start, at least until demand for them increases.

Nevertheless, there seems to be hope that alternative crops can provide new marketing and income opportunities for operators wanting to diversify. The key is to carefully analyze the situation first in order to choose the crop best suited for your situation.

Emerson Nafziger, associate professor of agronomy

Why Not Oats?

*Fred L. Kolb
and Charles M. Brown*

Over the past thirty years, the amount of oats harvested for grain in Illinois has decreased from about 2 million acres to 200,000 acres. The downscaling of oat production reflects a general decline in the diversity of the state's agriculture during the same period.

Oat acreage continues to decline despite a sharp increase in the demand for oats as a human food over the past five years. The demand for oats for human consumption has in fact doubled in that period.

In recent years, new discoveries regarding the desirable nutritional qualities of oats have made them popular with consumers. For instance, as part of a low-fat diet, the water-soluble fiber in oat bran and oatmeal has been shown to reduce serum cholesterol levels in individuals with high serum cholesterol. Considering the abundance of information available these days about the health risks associated with high cholesterol, the new attention given to oats should come as little surprise.

So, considering the new demand, why are Illinois farmers planting fewer acres to oats? Two major reasons for the drop in oat acreage are the reduced use of oats as livestock feed and the lower net return per acre when compared to other crops grown in Illinois.

Oats is the only grain crop for which the United States is a net importer. In 1989 about forty million bushels of oats were imported into the United States, primarily from Canada, Sweden, and Argentina. The imported oats were generally lower in grain quality and protein percentage than those grown in the United States.

Nutritious products such as oatmeal and oat bran muffins are good sources of water-soluble fiber.

For oats to be a suitable option for Illinois farmers, the economic return to the producer would need to be similar to that of other crops. But the government-guaranteed target price for oats has been low, and government farm programs have generally discouraged domestic oat production.

Increasing oat acreage would help to diversify Illinois agriculture. Oats provide an excellent alternative crop for sloping terrain where the soil is prone to erosion. Oats require low input — the cost of seed is low, and herbicides are usually not necessary. Thus, although gross return is lower for oats than for corn or soybeans, the cost of production is also lower. In some areas, farmers need the straw for livestock bedding, or they may sell the straw for additional income. Oats may also be used as a nurse crop for establishing legumes. Although oats traditionally require low input, yields are increased by proper fertilizer application based on nutrient requirements determined by soil testing.

In Illinois, oats are best suited to the cooler environment of the northern half of the state. Although oat is a cool-season crop, in a drought year like 1988 oats yielded well in comparison to corn and soybeans because the oats matured and were harvested in July before the most severe part of the drought. Therefore, in addition to increasing the diversity of Illinois agriculture, growing oats may reduce the risk of crop failure due to drought and other hazards.

Oat varieties now available produce higher yields and have better disease resistance and grain quality than varieties grown twenty or thirty years ago. Yields exceeding one hundred bushels per acre are common in Illinois. Many improved varieties of oats have been developed at the Illinois Agricultural Experiment Station. They include Ogle, Larry, Hazel, Don, Otee, and Lang. In 1989, 49 percent of the U.S. oat acreage used to produce certified seed was planted to varieties developed at the University of Illinois. The Agricultural Experiment Station's strong program in oat breeding has emphasized improvement in yield, grain quality, and disease resistance.

Considering the increased demand for oats and the crop's potential as an alternative to corn and soybeans in some cases, Illinois farmers should ask themselves, Why not oats? when considering diversifying their farming operations.

Fred L. Kolb, assistant professor of agronomy, and Charles M. Brown, professor emeritus of agronomy

Organically Grown Produce Finding Market Niche

John B. Masiunas and John M. Gerber

Today's emphasis on health and nutrition has prompted an increasing number of consumers to demand fresh produce grown without the use of synthetic pesticides, fertilizers, or growth hormones (Figure 1). In recent national surveys, 28 percent of consumers have sought produce grown either organically or with limited use of chemicals.

The most common organic produce today are tomatoes and apples. In a recent Louis Harris poll, 84 percent of consumers surveyed indicated a preference for organically grown fruits and vegetables if the cost was the same as other produce. Despite the increased demand for organic fruits and vegetables, growth of the industry has been slow.

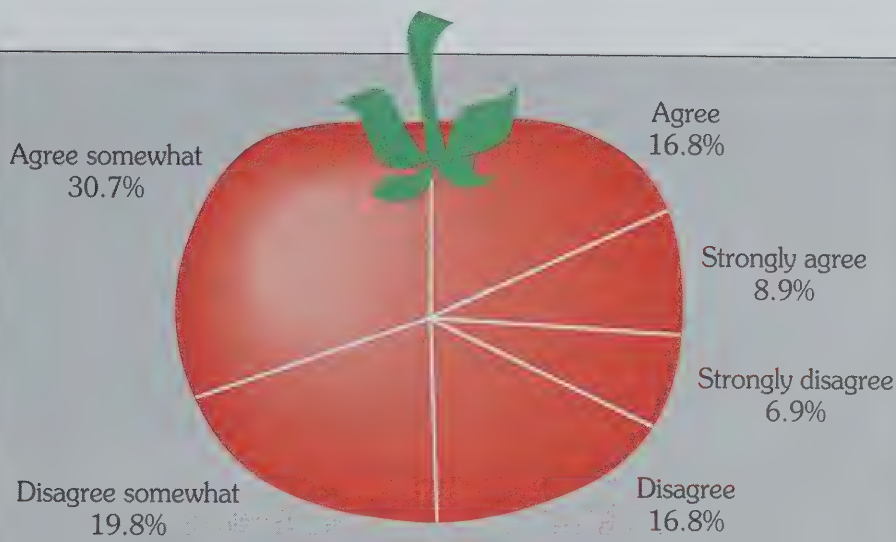


Figure 1. Response of fruit and vegetable consumers to the statement, "Regardless of cost, [I] would rather buy organic produce, grown without the use of chemical fertilizers and pesticides" (from a survey conducted in late 1989 by Market Facts, Inc.).

Organics in Illinois

In a recent survey conducted by University of Illinois researchers, 4.5 percent of the state's fruit and vegetable growers indicated they were organic — that they did not use synthetic pesticides. Fruit and vegetable growers practicing organic methods tend to farm fewer acres than conventional growers.

Organic fruit growers in the state average three acres of fruit, compared to twenty-one acres for conventional fruit growers (Table 1). Most of the organic fruits are either strawberries or brambles (blackberries and raspberries).

The state's organic vegetable growers farm more acres on average than its fruit growers, allowing them to rotate land among different vegetables. They average twelve acres of vegetables, compared to

Table 1.
A Comparison of Organic and Conventional Fruit and Vegetable Growers in Illinois

	Organic		Conventional	
	Total	Average	Total	Average
		acres		
Fruit	26	3	4,395	21
Vegetables	87	12	12,388	66
Total farm	1,881	125	62,614	205

Source: Masiunas, J.B. 1989. *Pest Management in Fresh Market Fruits and Vegetables.* Unpublished survey. University of Illinois.

an average of sixty-six acres for conventional growers. Organic vegetables grown in Illinois include a wide variety, everything from herbs and greens to tomatoes, squash, and peppers.

Organic growers are more likely to substitute on-farm resources for off-farm (purchased) resources than are conventional growers with similarly sized operations. Organic growers tend to use cover crops to improve soil tilth, cultivation and tillage to control weeds, and resistant fruit and vegetable varieties to control disease. In the University survey, organic fruit and vegetable growers indicated that they were especially concerned about soil erosion, contamination of ground water from agricultural chemicals, and pesticide residues in fruits and vegetables.

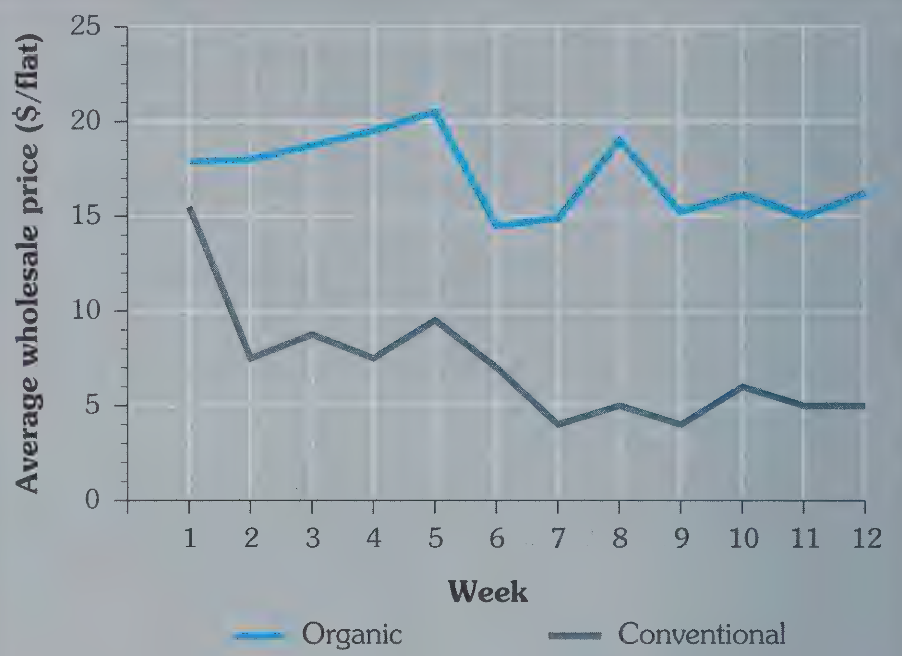


Figure 2. Comparison of the wholesale prices for organically and conventionally grown cherry tomatoes for the period of May 12 to July 28, 1989. The wholesale prices were those of California organic growers (organic) and of the Los Angeles Terminal Market (conventional).

Diversity of the Industry

Organic farming can be found in every region of the state, from the counties surrounding Chicago to Union County in southernmost Illinois. The crops grown and the marketing methods used to sell them are also very diverse.

Mike Michael owns Ladybug Farm, located in Spring Grove, near Chicago. Mike insists on delivering top-quality, farm-fresh organically grown herbs and vegetables to his customers. Emphasizing specialty items, he grows seventy varieties of greens and herbs. Ladybug Farm is renowned for its vine-ripened tomatoes. They are not the hard, flavorless varieties that have become the standard in grocery stores. Instead, Michael grows older, flavorful varieties such as Lemon Boy, Roma, and Valencia.

Ladybug Farm employs a unique marketing system. From the farm's establishment in 1982, its reputation for excellence has spread by word-of-mouth among restaurateurs. Today the company delivers fresh vegetables to a network of sixty Chicago-area restaurants five days a week. A half-dozen supermarket chains also sell Ladybug Farm products. To build retail customer loyalty, Ladybug Farm stickers are placed on each tomato fruit sold. It is now commonplace for customers to ask for Ladybug tomatoes by name, even after the season is over.

Love Apple Goes to Court

Whether the tomato is a fruit or a vegetable is a classic horticultural question. Technically it is a fruit because it develops from an ovary. But it traditionally has been treated as a vegetable. Even the highest court in the land has had to grapple with this question. In 1893 the U.S. Supreme Court ruled, "Botanically speaking, tomatoes are the fruit of a vine...but in the common language of the people, they are vegetables."

Another farmer, Stephen Smith of Pumpkin Hollow Farm, illustrates the diversity of the organic growers in Illinois. Like many others in the back-to-the-land movement of the 1970s, Steve left New York City in search of something that he felt was missing in his life. He found that elusive "something" in Anna, a rural community south of Carbondale. He has been farming in southern Illinois for twelve years now.

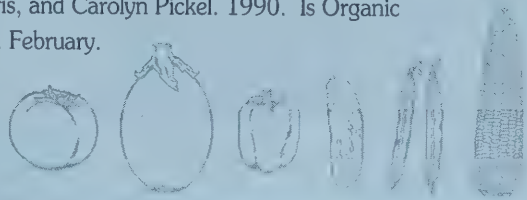
At Pumpkin Hollow Farm, Smith produces organically grown tomatoes, sweet corn, bell peppers, squash, leafy greens, onions, and more. He starts planting in February; begins harvesting greens in May; and is still selling pumpkins, squash, and sweet potatoes at the Carbondale farmers' market at Thanksgiving. The multiple plantings and intensive culture on his ten-acre farm keep food on his table year-round and ample supplies to sell at the market.

Unlike Mike Michael, Smith has seen his restaurant clientele dwindle over the years. When he started in 1977, his

Table 2.
Prices and Per-Acre Net Returns from Organic and Conventional Produce

	Price per pound		Net returns per acre	
Crop	Conventional	Organic	Conventional	Organic
	dollars			
Tomatoes	0.24	0.35	2,862	2,090
Eggplant	0.17	0.29	2,369	3,520
Peppers	0.17	0.34	187	1,218
Cucumbers	0.13	0.22	1,760	2,820
Snapbeans	0.21	0.35	193	191
Sweet corn	0.09	0.14	(-20)	(-150)

Source: Cook, Roberta, Kim Norris, and Carolyn Pickel. 1990. Is Organic Production Profitable? *The Grower*. February. Pp. 38–42.



clients included a number of small mom-and-pop establishments serving the students at Southern Illinois University at Carbondale. But many of those small establishments had to close their doors to business after the fast-food franchises came to town. And the fast-food franchises do not buy locally grown organic vegetables. So Steve now relies on farmers' markets, where he has built customer loyalty, to sell the fruits of his labor.

Limits on Growth of Industry

Three factors have restricted growth of the organic fruit and vegetable industry in Illinois. First, organically grown fruits and vegetables cost more than other produce, making them less attractive to consumers, especially middle-income and limited-income families (Table 2 and Figure 2). Organic production methods are more labor-intensive than conventional methods. The New Alchemy Institute in Falmouth, Massachusetts, estimates that of the total production costs for growing organic tomatoes, 50 percent goes toward labor. By contrast, labor accounts for less than 20 percent of the cost of conventional tomato production.

Another variable elevating the price of organic produce is the higher culling rates necessary for maintaining quality comparable to that of conventionally grown produce. The higher labor costs and greater culling rates often reduce the net return per acre for organic growers (Table 2).

A second factor limiting growth of the industry is the extreme price fluctuations characteristic of specialty agricultural products. Often, organic fruits and vegetables drop in price during the summer because of the high availability of locally produced and home-grown products. In the winter, prices may soar because of short supplies and long shipping distances. Consistent quality can also be a problem, since organic produce is often picked fully ripe and therefore has a shorter shelf life.

A third limitation is the lack of federal and state standards defining what is organic. Senator Patrick Leahy of Vermont and nineteen other senators have sponsored the Organic Foods Production Act to establish national standards for production of organic products and to standardize labeling.

Efforts are also under way to develop state labeling laws. In Illinois, organic growers have been working on an organic foods labeling act to assist in achieving product differentiation and to prevent potential fraud. Organizations involved in the effort include the Land of Lincoln Organic Growers Association, the Illinois chapter of the Organic Crop Improvement Association, the Illinois Consumers for Safe Food, the Illinois Stewardship Alliance, the Illinois Department of Agriculture, and the Illinois Specialty Growers Association.

Marketing Organics in Illinois

A traditional source of organic fruits and vegetables has been natural food stores and cooperatives. Natural food stores are generally found in larger Illinois cities, and some have handled organic produce for more than twenty years. This long-term commitment has allowed them to establish extensive networks of sources within the organic food industry. Many natural food stores and co-ops now stock a wide variety of quality fruits and vegetables. Gone are the early days of organics, when farmers could offer food stores only a narrow selection of poor-quality fruits and vegetables.

Green Earth in Evansville offers an innovative approach to natural-food retailing. Co-owned by Kyra Walsh and Karin Dittmar, Green Earth is not only a large food store but also a mail-order business carrying a full line of organic fruits and vegetables. During the summer, the business partners buy directly from local growers. At other times, they buy produce flown in from California. Walsh and Dittmar research their Illinois growers carefully, using questionnaires and visits to get to know them and their operations better.

Mike Michaels of Spring Grove delivers fresh vegetables to Chicago-area restaurants five days a week. (Photo courtesy of Ladybug Farm.)

Terminal markets and produce wholesalers have been an important source of conventionally grown fruits and vegetables. An increasing number of wholesalers in Illinois also specialize in organics. One example is Midwest Organic Produce, owned by Maurice Dayan. Since 1988 the company has operated out of the South Water Market, the terminal fruit and vegetable market in Chicago.

Much of Midwest Organic Produce's business is done with health food stores and co-ops, Chicago's more progressive and cosmopolitan niche grocery stores, local wholesalers, and trendy restaurants. To ensure a year-round supply of organic fruits and vegetables, they buy produce from the West Coast, Texas, and Florida.

Most consumers shop for produce in retail grocery stores and supermarkets. Some grocery stores in Illinois have attempted to stock organic items, but their efforts have not always been successful. It has been difficult for supermarket chains to find consistent quantities of organic products or to encourage customer recognition of organics. Thus, supermarkets generally have lagged behind smaller retail outlets in stocking such items.

Rosalie Ziomek, executive director of the Illinois Consumers for Safe Food, contends that for organic foods to become an important segment of the marketplace, large supermarket chains will have to routinely handle them. She advises consumers to use the power of the shopping cart to demand organic produce. If this effort is successful, the small market niche organics now occupy could become a major boon to Illinois agriculture.

John B. Masiunas, assistant professor of horticulture, and John M. Gerber, professor of horticulture and assistant director of the Agricultural Experiment Station

Tailor-Made Tomatoes

Charles E. Voigt and John A. Juvik

During the past twenty-five years, tomato marketing has greatly diversified based on end-product use. Today's increased marketing alternatives have prompted the development of specific varietal types genetically designed to satisfy the various consumer market segments.

Researchers at the University of Illinois are involved in the effort to develop new and improved tomato cultivars. These scientists are examining wild genetic resources and cultivated tomato varieties to survey for existing types that could fill specific market niches. In addition, they are working to identify individual transferable traits that can be used to improve the quality or versatility of varieties already well suited to market demands.

Plant breeders in the United States have developed specialized tomato varieties suitable for processing and canning, fresh-market sales, or the home garden. The greatest proportion of the nation's tomato acreage is grown for processing. These tomatoes are machine-harvested at the red-ripe stage, then either canned whole or pureed and partially dehydrated to produce juice, sauce, paste, and ketchup.

Recent research at the University has focused on increasing fruit-soluble solids, composed primarily of sugars, organic acids, and proteins. These solids represent 60 percent of the tomato's dry weight. With a higher soluble-solids content, net yield and fruit quality increase while costs for dehydration decrease.

Commercial fresh-market tomatoes constitute another significant economic niche in tomato production. Generally, these tomatoes are harvested by hand just prior to displaying the red pigment associated with ripening. They complete ripening during shipment. Fresh-market

breeding work is aimed at developing varieties with uniform shape, size, color, and flavor. Scientists at the University are studying the feasibility of using a parthenocarpic gene that induces seedless fruit. Studies have shown that these parthenocarpic fruit can develop without pollination. They are therefore less sensitive to extreme environmental conditions known to inhibit pollination.

With home-garden tomato varieties, insect and disease resistance as well as taste and growth habit are important. University researchers, in conjunction with the Monsanto Company, are investigating the potential use of tomato plants containing a gene from *Bacillus thuringiensis* that confers improved resistance to insects. Tomato genotypes have been genetically engineered to contain and express this bacterial gene, which can synthesize a protein highly toxic to a number of species of insect pests but is harmless to humans. Greenhouse and field tests suggest that these genetically engineered plants possess sufficient resistance to allow for the reduction or elimination of insecticidal sprays, thus improving consumer safety and reducing grower production costs.

Wild Species
and Early Landraces Developed
by Pre-Columbian Civilizations
in South and Central America

⇓

Introduction into Europe
and North America

⇓

Development of Landraces
and Older Varieties
Adapted to Temperate Climates

⇓

Use of Genetic Diversity
to Create Specific Marketing Types
by Modern Breeding Technology

Figure 1. Tomato genetic variation.

Very recently, a specialized commercial market has developed for novelty tomato types. The more distinct the tomato's color, shape, size, and taste, the greater its appeal to curious consumers. To try to identify material that might expand the tomato market further in this direction, surveys are being conducted at the University on a large number of older "heirloom" varieties. This research is being done in cooperation with the Seed Savers' Exchange. The varieties being evaluated include tomatoes from the size of garden peas to much larger fruits weighing several pounds. Also being evaluated are tomatoes with variations in color — from red, yellow, orange, and green (when ripe) to white, pink, and purple.

To successfully compete for an expanding share of the consumer market, all agricultural commodities must diversify their end-product use. In the case of the tomato, the genetic diversity created in the past and maintained by our ancestors has fueled the development of varieties tailor-made for today's specialty markets.

Charles E. Voigt, research specialist in agriculture, and John A. Juvik, associate professor of plant genetics, Department of Horticulture

The tomato genus Lycopersicon, *native to South America and Central America, includes eight species, all of which can be hybridized with the cultivated tomato,* Lycopersicon esculentum. *The result is a large wild gene pool available to plant breeders interested in developing new and unique genotypes to fill new market niches. Although wild ancestral tomato fruits were only the size of peas, selection and domestication by pre-Columbian agriculturists and later development in Europe and North America have created an array of types and sizes with amazing genetic diversity. These subspecies, varieties, and landraces have been a valuable legacy for twentieth-century breeding programs. (Photo courtesy of Charles Voigt.)*

Policies to Create Diversity in Illinois Agriculture

Harold D. Guither

Farmers are becoming increasingly interested in diversifying their agricultural operations. Meetings, conferences, and exhibitions focusing on new and alternative farm enterprises have become popular and well attended. But whether interest can be shifted to action depends on the economics of changing enterprises and the public policies that will encourage or discourage such decisions.

What the Farmers Think

In February 1989, a group of agricultural economists from twenty-one states cooperated in a nationwide survey of farmers' preferences concerning federal agricultural and food policies. The survey, sponsored by the National Public Policy Education Committee, provided valuable information on farmers' concerns regarding the Food Security Act of 1985 and the new 1990 farm bill. One thousand Illinois farm operators participated in the survey.

The survey results indicated a willingness on the part of Illinois farmers to diversify their farm operations. Twelve percent of the Illinois farmers surveyed reported having grown new crops or started some new livestock, poultry, or other enterprise some time in the previous five years. Among the new enterprises reported were crops (49 percent), livestock or poultry (40 percent), and services (11 percent). Thirty-four percent said they would produce a new crop in 1989.

Current farm programs and policies affect farmers' desire to grow new crops or start other money-making enterprises. When asked whether more flexibility in farm program acreage rules would encourage them to grow new crops or start other enterprises, 37 percent of the Illinois farmers surveyed said yes.

Policies that provide help to farmers who want to try new farm enterprises could encourage more agricultural diversity. Table 1 lists the kinds of help farmers need most to diversify their operations.

Table 1.
Help U.S. Farmers Need Most to Start New Enterprises

	percent
Research-backed information on cultural practices	62
Contract or dependable firm to buy the product	50
Low-interest loans to finance new crop or enterprise	44
Farm program that permits growing new crop without loss of acreage base for program crop	31
More information on production costs	19
Commodity price support loans	2

Source: University of Illinois. July 1990. *New Agricultural and Rural Enterprises for Illinois Farmers*. AE4666. Department of Agricultural Economics, College of Agriculture, Agricultural Experiment Station.

The Policy Maker's Role

The responses of farmers participating in the survey indicate that they have explored the idea of diversification and that many are receptive to change. Implementing certain policies at both the state and federal levels could accelerate farmers' decisions to diversify.

One of the most important areas for policy makers to consider is public funding for continuing-education and research programs. Farmers interested in starting new service enterprises, for example, need to acquire knowledge of business management. They also benefit from talking with peers and experts with knowledge of the subject. Cooperative Extension classes, meetings, and field demonstrations are all part of farmers' continuing education.

Farmers wanting to diversify their operations would also benefit from research on the most efficient and profitable methods of production for new crop, livestock, and poultry enterprises. Without thorough knowledge of cultural and management practices, new enterprises pose high risks. Farmers are not likely to try something new unless they see a potential for success.


Raising vegetable crops may be a means for some Illinois farmers to diversify.

In the survey, farmers said they would prefer to sell a new product under a contract or have dependable buyers. To enhance efficient marketing, new policies could establish grade standards for new crops, livestock, or poultry; publish market price information; develop supply-and-demand estimates; and assist with export market development if the new commodities have international market potential.

Low-priced credit could encourage diversity where capital is required to implement a new enterprise. Current policies would allow lower-cost credit from the Farmers Home Administration for those farmers who could not get credit from other sources. Usually Farmers Home Administration loans require a lower interest rate and are offered to young farmers. A policy to encourage loans for new farming enterprises might stimulate the diversification process.

Farm Subsidies and Program Crops

Farm commodity programs have encouraged production of program crops for which a target price, loan rate, and deficiency payment are established. The acreage bases encourage continued production of the program crop because of the potential deficiency payment. Failure to maintain production on the crop acreage base has in the past resulted in loss of part of the crop base.

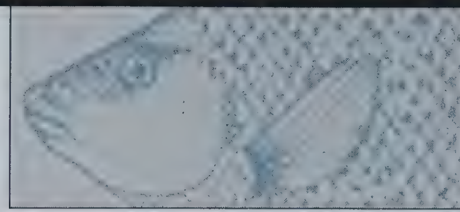
Now flexibility has become the buzzword in farm policy reform. The 1988 Disaster Assistance Act permitted farmers to plant part of their crop base acreage to soybeans or sunflowers. In Illinois, this meant substitution from part of the feed grain or wheat base. But farmers who made a substitution would not lose the historic record of corn or wheat base. A similar substitution was permitted in 1990. Flexibility has also made it possible for other nonprogram crops to be grown on program crop acreage bases. The early experience with this flexible approach suggests that some farmers will take advantage of this substitution opportunity, but market prices also influence these decisions.

The 1990 farm legislation is expected to include some flexibility features that permit farmers to diversify their cropping program without loss of the historic crop acreage base that they regard so highly as insurance for the future if large acreage reduction programs are required.

Detailed production costs might help farmers determine whether they have a chance for a profit on a new crop or livestock enterprise. Special grants could be given to develop this kind of detailed data.

If farmers are to diversify their operations, public policies must be compatible with these changes. Policies can either encourage or discourage the movement toward diversity. For every policy decision there is a consequence. If the desired policy goal is to encourage diversity, then some of the policy decisions discussed here must be made to help facilitate this goal.

Harold D. Guither, professor of agricultural policy, Department of Agricultural Economics



Meat Industry Caters to Consumers

Peter J. Bechtel and Floyd K. McKeith

Americans are changing their eating habits, reflecting a new emphasis on health and fitness. As a result, the food industry is offering more diverse products to fit the new lifestyles of consumers. In the Illinois meat industry, the trend has been toward expanding the number of products within the traditional beef and pork sectors along with introducing other animals, such as fish and poultry, to satisfy our increasing appetite for diverse foods.

Illinois Animal and Meat Industries

The increasing diversification of domestic food animals in Illinois reflects what is happening nationwide. The major species in Illinois are hogs, cattle, horses, chickens, turkeys, and sheep.

Major meat animal species and their values are shown in Tables 1 and 2. In terms of both numbers and value, the pig is the state's dominant meat animal. Although hog numbers have decreased during the past decade, cash receipts have remained rather constant. During the same period, cattle and calf numbers have decreased, though cash receipts have increased. The sheep and lamb industry has been relatively static during the past decade.

An often-overlooked component of the state's animal industry is the horse. The Illinois horse population, numbering around 150,000, has remained steady during the past five years. The species is important for a variety of reasons, one being that they consume large quantities of locally produced feed. They are also valued as pleasure animals (riding and racing) and draft animals. To a lesser extent, they are used for milk, meat, and leather. The horse industry is a significant component of the state's total farm animal enterprise.

A large number of minor species fill niche markets in Illinois for both meat and other uses. An active rabbit industry provides meat for specialty restaurants. A small but thriving goat industry provides milk and meat. Game farms produce deer and buffalo meat. The state also produces fish, crayfish, bees, laboratory animals, llamas, mink, and fox.

Aquaculture is an active and growing segment of the animal industry. Once restricted to warmer climates in the United States, the industry has now expanded northward. The producer-oriented Illinois Aquaculture Association was recently formed to help guide and monitor the industry within the state. Fish grown in the state include sea bass, catfish, and tilapia (tropical freshwater fish resembling sunfish). The state has also spawned a small crayfish industry.

Table 1.
Illinois Farm Animal Numbers

	1979	1984	1989
	- - - - - - - thousands - - - - - -		
Hogs	6,550	5,400	5,600
Cattle and calves	2,850	2,600	1,950
Sheep and lambs	184	145	140

Source: U.S. Department of Agriculture as listed in *MeatFacts* (1979, 1984, and 1989), published by the American Meat Institute.

Table 2.
Illinois Cash Receipts for Meat Animals

	1978	1983	1988
	- - - - - - - millions - - - - - - - -		
Hogs	$1,091	$1,124	$1,024
Cattle and calves	702	745	812
Sheep and lambs	6	6	6
Total	1,799	1,875	1,842

Source: U.S. Department of Agriculture as listed in *MeatFacts* (1979, 1984, and 1989), published by the American Meat Institute.

Tilapia

A recent trend in the non-meat animal industry has been an increase of exotic species. An example is the llama, sold at auction centers in a number of states. In Illinois and elsewhere, mink and fox ranches supply the fur industry.

Also worth mentioning is the insect sector of the animal industry. Bees are used for pollination and production of honey. And insects for biological control of crop pests have become a reality.

Meat Product Diversity

Changes in meat consumption in the United States are shown in Table 3. The trend toward diversification can be readily seen in the number of products targeted to different market segments. Many of these products are "branded," which means they are labeled and promoted by a company. This concept is quite old for processed meats such as frankfurters, sausages, and luncheon meats. Fresh red

Table 3.
U.S. Per-Capita Consumption of Red Meat, Poultry, and Fish

	Boneless equivalent 1968	1978	1988
		pounds	
Beef	77.3	82.3	68.6
Pork	49.4	40.4	44.7
Chicken	25.4	32.1	44.3
Fish	11.0	13.4	15.0
Turkey	6.4	7.2	12.8
Veal	2.6	2.0	1.2
Lamb	2.4	1.0	1.0

Source: U.S. Department of Agriculture as listed in *MeatFacts* (1989), published by the American Meat Institute.

Aquaculture is an active and growing segment of the Illinois meat industry.

meats, however, have traditionally been cut by local butchers and sold as a kind of commodity. Thus, branded fresh meat is a relatively new concept. It should be pointed out that fresh poultry is often sold under a brand name (Holly Farms, for example). With the identification of unique markets for fresh meats, a number of new products have been tailored to fill these niches.

Meat producers are using several strategies to market fresh beef. One successful venture has been the Certified Angus Beef program, which has targeted the upscale market with a high-quality, tender, traditional beef. Sales of Certified Angus Beef have shown good growth and have strong consumer, restaurant, and export markets.

The diet and health markets have also been targeted for unique branded beef products. One segment of this group uses labeling claims to promote the nonuse of hormones, antibiotics, and growth stimulants. Several examples are Coleman's Natural Beef, Ranch Connection Beef, and Natural Lite Beef. It should be noted that several companies are emphasizing hormone- and antibiotic-free poultry as well.

Brand-labeled meats containing reduced calories per serving are also being marketed. The U.S. Department of Agriculture monitors and controls the use of claims on meat products such as "lite" or "extra lean." Brand names such as Key-lite and Laura's Lean Beef are examples of beef merchandised for consumers wanting quality, low-fat fresh meats. Some supermarket chains are providing fresh meat products with lower fat contents by purchasing meat with less marbling and removing more fat during trimming. During the past ten years, the pork industry has produced lower-fat products such as 95 percent fat-free ham and low-fat luncheon meats.

Convenience-oriented meat products are also entering the marketplace. A number of companies, including Excel and Hormel, are producing closely trimmed "individual" meat portions packaged in vacuum containers. These "peg-board" packages have an extended shelf life when refrigerated and provide individual portions. Also, because the product is packaged at a centralized meat cutting facility, the store does not have to employ a meat cutter. A number of other companies are also producing precooked and microwavable steaks and roasts. Companies such as Con Agra, Bryan Foods, Bil Mar Foods, and Kroger are exploring new ways to exploit the growing markets for precooked and microwavable products.

An interesting trend in the food industry has been the marketing of ethnic food products. The meat industry has played a major role in this development by providing unique products to meet the demands for many colorful and flavorful ethnic cuisines. Scaloppini slices, stir fry meats, Italian sausages, bratwurst, meat for gyro sandwiches, and smoked goose wings are but a sampling of the diversity in ethnic meats.

Turkeys Take Off

Ken W. Koelkebeck

U.S. turkey production and consumption are up and have been for some time. And local producers wisely have involved themselves in this growth industry.

According to the Illinois Agricultural Statistics Service, the 1989 value of production (based on a market price of $0.40 per pound) for the state's turkey industry exceeded $34 million. That was more than double the previous year's figure.

By increasing production, turkey growers have simply responded to the demands of the market. Total U.S. turkey consumption has increased dramatically over the past ten years. In 1980, 2.5 billion pounds of turkey was enough to satisfy our appetite for this meat. By 1989 that figure had risen to 5 billion pounds.

As our society grows increasingly health conscious, it is not surprising that more and more people are making turkey part of their regular diet. An excellent source of protein, turkey contains less total fat and calories than beef, pork, or lamb (Table 1). Per-capita consumption of turkey has risen from 10.5 pounds in 1980 to 16.9 pounds in 1989.

Besides being nutritious, turkey is a versatile food. Its uses range from the traditional whole bird for Thanksgiving dinner to ham, pastrami, bologna, bratwurst, and ground turkey (a good substitute for ground beef).

Responding to increased turkey consumption and a forecast for this trend to continue, turkey companies across the country have stepped up production over the past five years. During this time, Illinois turkey production has jumped from about 350,000 to roughly 3.7 million birds per year.

Two major companies, along with a few independent growers, now raise turkeys in Illinois. The biggest are Trevcam, Inc., and Perdue Turkey Farms. In terms of production, the largest of the two is Quincy-based Trevcam, which produced roughly 2.7 million turkeys in 1989 on about fifty contract grow-out farms. Perdue, based in Indiana, contracts out to about thirty growers in Illinois, mainly in Lawrence County, on the Indiana border. Its Illinois production amounts to approximately 1 million birds annually.

A number of factors have contributed to the dramatic growth in the state's turkey industry. These include a surplus of feed grain (corn and soybeans); a favorable growing climate; an availability of adequate land; a close proximity to retail markets (Chicago, St. Louis, and Indianapolis); and a good highway transportation system. The growth has occurred despite some significant drawbacks, such as a negative attitude of some farmers and lending institutions about the industry's viability; farmers'

Although a small number of turkeys are raised "on range" as shown, most are produced in confinement.

general unfamiliarity with contract production; and the state's relatively high tax and workers' compensation rates.

Illinois farmers who have decided to grow turkeys on contract for major companies have found it to be an effective way to diversify their farming operations. Considering the many advantages the state offers for poultry production, combined with the prospect of an increasing demand for turkey products, the outlook appears to be bright for local turkey farmers.

Ken W. Koelkebeck, poultry Extension specialist

Table 1.
Nutrient Values for Turkey, Lamb, Beef, and Pork

	Calories	Fat	Protein	Cholesterol
	per 3-ounce cooked serving			
Turkey	129	2.6 grams	25 grams	64 milligrams
Lamb	176	8.1 grams	24 grams	78 milligrams
Beef	192	9.4 grams	25 grams	73 milligrams
Pork	198	11.1 grams	23 grams	79 milligrams

Source: U.S. Department of Agriculture.

Consumer Diversity

It has been apparent for a number of years that meat products can be successfully targeted to different groups of consumers. One clear trend in our society is the aging of the population, which will have an impact on meat purchases. The increase in the number of elderly will result in smaller households, smaller mealtime meat portions, greater health and nutrition concerns, and in many cases more disposable income to spend on quality and convenience-positioned products.

Over the last several years, on-the-go and health-oriented consumer segments have also increased, while the number of "meat lovers" has dwindled. Many producers are following changes in consumer preferences to effectively target their products toward specific market segments.

As a major red-meat producer and food and meat processing center, Illinois must continue to provide a wide array of products to satisfy the many consumer markets both here and across the nation.

Peter J. Bechtel, former professor, and Floyd K. McKeith, associate professor, of animal sciences*

* Now professor and head of the Department of Food Science and Human Nutrition, Colorado State University.

Specialty Meats

Tina Prow

Every food store carries meat, but few offer the service shoppers get at Thrushwood Farms Quality Meats, Inc., in Galesburg. And none carries Thrushwood Farms' award-winning hams.

"In order to compete, we have to have a product that's better and special service to go along with it," says Jim Hankes, who runs Galesburg's only complete meat operation with his wife, Kay. "For instance, we've got a good reputation for what we do with pork. Our hams are mild-cured, without water or juices added. They've taken state and national awards, and people just go wild over the cuts we serve in the catering line.

"You just can't buy that kind of ham in stores anymore."

On opening day in 1978, the Hankes filled their meat cases with fresh-cut beef and pork, not expecting to offer much beyond custom butchering. Today, however, things are different. With sales of more than $1 million annually, Thrushwood Farms retails, wholesales, and custom-butchers meats. A deli area is stocked with an array of sandwich makings, salads, and cheeses. A freezer holds seafood, fruits, and some meats. The selection on a full-service catering menu ranges from meat and cheese trays to sandwiches and sausages to ribeye steaks and hog roasts.

"In 1978, we weren't concerned about specialty markets. But we lost some markets and looked around for new ones," Jim says. "We gradually added more service, equipment, and showcases. The specialty store just evolved and grew with the markets we found."

Those markets are built on customer demand for services and products no one else offers, he says. But filling customer demand is only part of the Hankes family's strategy for growth.

They also work at creating demand among Galesburg's thirty-five thousand residents. The shop offers samples and sales specials to entice customers to try new foods. And aggressive advertising campaigns let people know where they can find specialty catering, "the best Easter hams," and meats that will make them "cookout kings."

"You have to stay visible in your market, and word-of-mouth only takes you so far. We saturate the market, use repetition to let our customers know we're still out there, ride on our laurels for a while, and then hit again.

"It's difficult to spend money on advertising because the results are so hard to measure. But it's necessary," Jim says. "You might have the right equipment and technology and put out a good product, but if you don't sell that product, you won't get very far."

The Hankes credit some of the success of Thrushwood Farms to education and preparation that made for a solid business foundation. A job at the University of Illinois meats lab gave Jim real-world experience while he earned a bachelor's degree in animal science and a master's in meat science. Kay's course work for a bachelor's degree in home economics education, also at the University, proved to be vital when the business added deli and catering markets.

Before breaking ground for the business, they researched demographics, created an ideal meat plant on paper, investigated costs, and worked with an accountant to put together a five-year business plan.

Owner Jim Hankes displays a Thrushwood Farms award-winner. (Photo courtesy Thrushwood Farms)

Even after being in the business more than a decade, they still attend seminars, workshops, and meetings to stay current with new developments, ideas, and trends. This year, Jim is president of the American Association of Meat Processors.

"We're bigger than we ever imagined we could be, and there is potential to expand even further," he says. "We've evolved and grown because with our knowledge we can take a product and make it better. That's kind of fun."

Tina Prow, Extension communications specialist

Illinois Agriculture in Transition: An Ecological Perspective

Richard E. Warner

The American public is becoming increasingly aware of and concerned about modern agriculture's effect on the environment. The Food Security Acts of 1985 and those pending for 1990 reflect the non-farm sector's heightened involvement in such environmental issues.

To understand the dynamics underlying this new public concern, one must look at the history of U.S. agricultural ecosystems and the way in which farmers have interacted with their land resources.

Historical Patterns in Agricultural Ecosystems

Illinois, especially its central counties, has been a leader among states in the adoption of new farming methods and technologies. From an ecological perspective, the prairie state has been in the eye of the storm — an environmental storm of sorts — because many modern farming practices have profoundly altered natural ecosystems. In short, Illinois has been a bellwether among the most intensively cropped regions of the world.

There is little doubt that human settlement greatly changed the face of Illinois; by 1980 only 0.5 percent of the state's vegetation remained relatively pristine. Consequently, the rate of plant and animal extinctions has been significant. For example, about 1 percent of the world's 9,000 bird species have become extinct, but a much higher percentage of the avifauna of Illinois has been lost. In fact, since the early 1800s about 5 percent of the fishes, birds, and mammals in Illinois have been exterminated, and another 15 percent of these species are now listed as endangered or threatened.

Illinois agriculture has always been dynamic, and from an ecological perspective these changes fall into three relatively distinct periods. The first, from the mid-1800s through the early 1900s, encompassed settlement farming and emerging agriculture. Presettlement Illinois had several ecological regions that were unique with respect to climatic gradients, geology, soil morphology, flora and fauna, and land forms. However, the more subtle differences in flora and fauna among regions had already diminished in the late 1800s as agronomic practices associated with a developing commercial agriculture became standardized. By 1920 precious little prairie had escaped draining and plowing.

Although settlement had dramatically affected vegetation in Illinois by the late 1800s, grasslands remained common during the era of diversified commercial farming that persisted from the early 1900s through World War II. During this period, forage crops — primarily introduced grasses and legumes — were integral to rotation farming, the production of livestock, and the seeding of fields periodically diverted from production by farm programs. Many prairie vertebrates survived and even thrived in the patchwork of small farms with forage crops and cereal and feed grains in rotation.

After World War II, the era of small, diversified commercial farming came to a close, and the third period of relatively large-scale specialized farming followed. This change-oriented era has been marked by an ever-expanding array of technological innovations. From an ecological standpoint, these changes are responsible for unprecedented chemical and mechanical perturbations of farm landscapes. The diversity and abundance of terrestrial plants and animals have taken yet another turn for the worse.

Changes in aquatic environments have been no less dramatic, as agriculture continues to alter the physical and chemical characteristics of streams, bottomland lakes, and rivers. Indeed, as high rates of sedimentation have occurred, the links between terrestrial and aquatic ecosystems have become increasingly apparent.

Thus, the contemporary farm landscapes of Illinois have become harsh environments for most native flora and fauna. The agricultural practices that have become widespread since World War II have further minimized distinctions among the ecological regions of Illinois. Relatively few native plants and animals are now abundant, and many of those that responded positively to farming are now subject to few natural checks and balances. They often require sustained human intervention to keep them from becoming economic pests.

Post–World War II farming methods have also acutely affected the pathways by which nutrients and energy are transferred to living organisms, and in terms of energy investment those pathways are highly inefficient. On the other hand, the pathways by which energy from the sun was stored and transferred in the prairie

ecosystem — food webs that included a diversity and abundance of soil microbes, plants, invertebrates, and vertebrates — have gradually fallen apart. In terms of biomass produced per unit of energy, modern farming systems are again inefficient because they depend on chemical fertilizers and pesticides that require large investments of petroleum-based products and energy during manufacture. These phenomena are, of course, integral to discussions of sustainable agriculture.

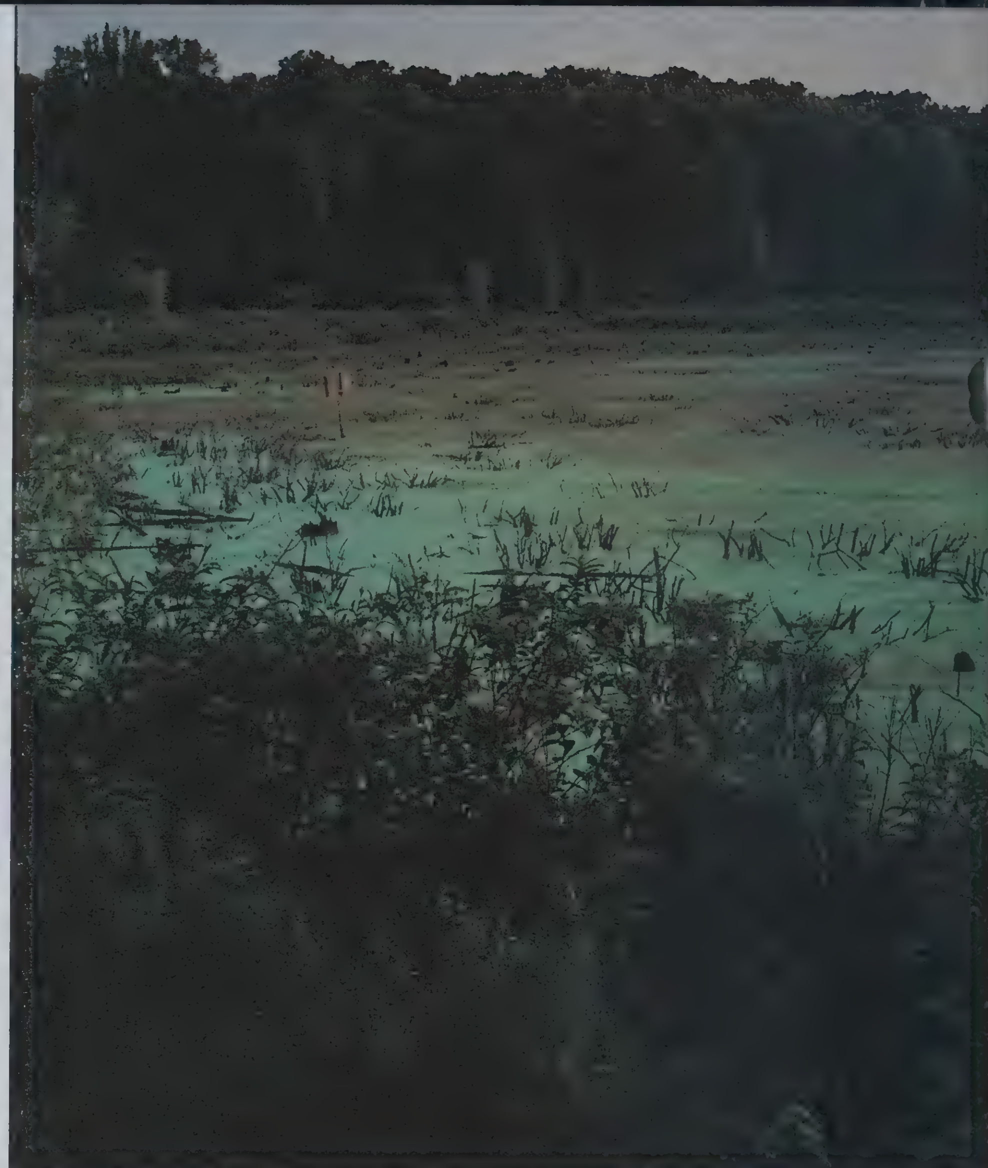
Ecologically Based Transitions

As far back as the mid-1800s, some indicators foretold of environmental upheaval in Illinois's future. The first census of agriculture in the United States, taken in 1850, documented that central Illinois had the highest farmland prices in the nation. Before agricultural settlement was complete, the state's deep, dark prairie soils were appreciated in the marketplace for their great agronomic potential.

Over the years, high land prices and high expectations have motivated Illinois farmers to maximize production. At times this desire to push production to its limit has jeopardized the land's long-term sustainability. As a result, a significant amount of topsoil has been lost, irreplaceable wetlands have been drained, a variety of wildlife habitats has been eliminated, and streams have been chemically and physically altered. Further, farm programs over the decades have not been able to stop the degradation of natural resources. In fact, these programs have often encouraged more intensive cropping.

Long-term patterns of change in farming reflect fundamental interactions between farmers and the land resource, governmental intervention through policies and programs, changing technologies, shifting farm economies and agricultural infrastructures, and the inherent uncertainties of weather and life itself. Indeed, an emphasis on survival has colored the relationship between farmers and the land in different ways at different times.

Especially for pioneer farmers, physical survival was preeminent. Given that



Prairie aquatic environments such as this wetlands have been threatened by agriculture ever since the pioneer days.

about half of the children in midwestern farm families of the mid-1800s died before reaching puberty, this emphasis is not surprising. Frontier farmers viewed many animals as vermin. And prairie wetlands with their profuse insects were considered a threat to human health and prosperity. With such innovations as the window screen and the plow, settlers after the Civil War wasted no time in conquering the prairie.

By the late 1800s and early 1900s, economic survival became the critical issue, and the period was marked by periodic crop failures and an economic depression. During the 1900s, the farm sector instinctively directed attention to coping with "boom-and-bust" markets and innovations related to profit. Few really grasped the ecological implications of changing land use.

Looking back, we now recognize that the ecosystems that created Illinois's rich prairie soils, an agricultural marvel, no longer exist. Farm landscapes have changed so dramatically from one generation to the next that Illinoisans now have little awareness of, or appreciation for, how these ecosystems once functioned. Nor do they understand those ecosystems' potential for harnessing energy from the sun.

At this point in time, members of the farm community cannot agree on how to create a stewardship of the land, partly because the fundamental properties of ecosystems seem so remote. To some, a "land ethic" means all-out production to

feed a hungry world. At the other extreme, some farmers are frustrated because of the limited resources available to encourage the preservation or restoration of such natural resources as topsoil, pristine streams, and wildlife.

Regardless of where given farmers stand on issues such as full production versus topsoil for their grandchildren, day-to-day constraints of economic survival play short-term profits against long-term, ecologically sound farming practices. Precisely at this tension point, signals from society have been mixed.

Society as a whole — and its farm policies and programs in particular — has contributed to a disjointed approach to the management of land and water resources. For example, the federal government for decades has offered programs to subsidize (encourage) the channelization of streams, thus destroying many of their natural attributes and exacerbating the effects of pollution. Agricultural programs have also encouraged the farming of land only marginally suited for crops.

Wetlands provide yet another contemporary example of mixed signals from policy makers. For decades, the federal government has provided assistance for draining moist soils for cropping. Since the mid-1980s, however, momentum has been growing — primarily in the nonfarm sector — to protect and restore these habitats.

The federal government's abrupt turnaround on wetland issues has perplexed the agricultural community. At the same time, environmental groups view it as too little too late. The haunting question is, What would have happened if a sustained wetlands conservation effort had been integrated with farm policies and programs decades ago? Had this been the case, the overproduction of farm commodities would have been moderated, relatively pristine tracts of wetlands would have been preserved, and the farm community would have received a consistent message regarding the values of wetlands and the incentives to protect them — *before* it was too late.

Thus, public policy has helped shape farmers' long-term attitudes about land use and natural resources. Farmers have also had to consider their economic, if not personal, survival.

The neglect of ecological considerations has come at a tragic cost. But even the current era of environmental awareness and regulation will not necessarily produce more ecologically sound farming systems or develop a land ethic among those who fill America's bread basket. Environmental issues related to agriculture are a fairly new crisis to the public, and society at large has a short attention span for such crises.

The marriage of agriculture and ecology needs a long courtship. Is the public willing to make a sustained investment in research and education to make the marriage work? Aside from the threat of environmental regulation, does the agricultural sector have genuine interest in implementing ecologically appropriate farming systems?

As we ponder the future of agriculture, we should remember that Illinois is a bellwether for agricultural change. The farming concepts and practices that emerge from our ecological stress points may well determine the characteristics of many intensively farmed regions of the nation and the world.

Richard E. Warner, wildlife ecologist, Illinois Natural History Survey

Nursery Crops: A Growing Success

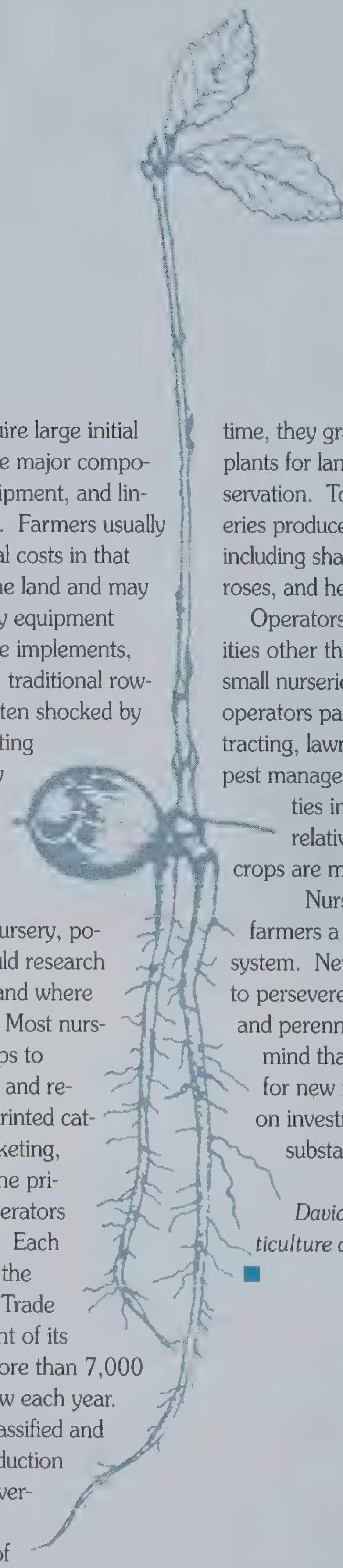
David Williams

The U.S. nursery industry blossomed during the 1980s. Since 1982, the greenhouse-nursery industry has grown at an average annual rate of 10 percent and in 1988 accounted for 9.6 percent of all farm-crop cash receipts. Aggregate greenhouse-nursery cash receipts for the United States totaled $6.9 billion in 1988, double the figure for 1980.

The demand for nursery crops continues to exceed the supply. Only in times of deep building recessions have decreases in the demand for these crops been felt. Nursery production in Illinois has expanded as long-time growers have increased their acreage and many new producers have entered the marketplace.

Illinois is an ideal state for nurseries in terms of both location and climate. Operators here have access to the urban markets of the Midwest and the East Coast. And, because it is geographically a long state, Illinois encompasses three U.S. Department of Agriculture hardiness zones. The average annual minimum temperature in these zones ranges from -20°F in the north (zone 5) to 0°F in the south (zone 7). This variety of climates enables growers to produce a multitude of crops — from dogwood and azaleas in the south to large shade trees and shrubs, the bread and butter of the north.

The high cash returns per acre have prompted many investors to inquire about growing nursery crops. Gross cash returns per acre commonly reach $50,000 to $60,000 for shade trees and $35,000 to $55,000 for shrubs. However, it is important to understand that the bottom line is profits, not gross income. Shrubs take from three to four years and trees four to seven years to reach harvestable size after planting.



Nursery crops require large initial start-up costs, with the major components being land, equipment, and linings-out stock (plants). Farmers usually have a leg up on initial costs in that they have access to the land and may already own necessary equipment such as tractors, tillage implements, and trucks. However, traditional row-crop producers are often shocked by the high costs of planting stock. Costs routinely run from $6,000 to $7,000 for trees and from $1,500 to $4,000 for shrubs.

Before starting a nursery, potential producers should research which crops to grow and where to sell their products. Most nurseries market their crops to landscape contractors and retail garden centers. Printed catalogs, direct-mail marketing, and trade shows are the primary tools nursery operators use to sell their crops. Each January, Illinois hosts the Mid-America Nursery Trade Show, the largest event of its kind in the nation. More than 7,000 people attend the show each year.

Nurseries can be classified and described by their production methods (that is, field versus container production), or by the types of plants they produce. In the past, nurseries typically produced fruit plants. Over time, they gradually began to include plants for landscaping, forestry, and conservation. Today most wholesale nurseries produce a variety of plant material, including shade trees, evergreens, shrubs, roses, and herbaceous perennials.

Operators often get involved in activities other than plant growing. Many small nurseries and new operators participate in landscape contracting, lawn care, tree pruning, and pest management. These diverse activities improve cash flow until the relatively slow-growing nursery crops are marketable.

Nursery crop production offers farmers a viable alternative cropping system. New producers should be able to persevere high initial investment costs and perennial crop cycles. But keep in mind that patience is truly a virtue for new nursery owners — the return on investment, though potentially substantial, will take time.

David Williams, professor of horticulture and Extension specialist

In Progress

Using Fly Ash to Study Soil Erosion

Soil researchers at the University of Illinois have uncovered a new method for determining levels of erosion caused by farming.

"For the first time, we can go into a basin and really identify the accumulation of sediments due to modern erosion," said Robert Jones of the Department of Agronomy. Jones developed the method with Kenneth Olson, a colleague in the department.

The technique involves testing soil for the presence of fly ash, small particles of residue from the burning of bituminous coal. Locomotives and steam-powered farm machinery used in the mid- to late 1800s were the first sources of fly ash in the Illinois soil surface. This time frame corresponds with the onset of widespread farming by settlers in the state. More recently, coal-fired power plants have added to the amount of fly ash in the environment.

Rain, the major cause of erosion in Illinois, washes unstable, intensively cultivated soils to sedimentation sites such as sideslopes and floodplains. Sedimentation sites thus contain more fly ash than do unstable soils.

Using the new technique, scientists can compare the amount of fly ash in stable, uncultivated sites with the amount found in nearby sedimentation sites. This information tells them how much sedimentation has occurred since settlers began farming the region about 130 years ago. This data also allows them to extrapolate rates of erosion.

"Geologic erosion and sedimentation was occurring long before European settlement of the area," Olson said. "What we needed was a way to separate geologic erosion from modern, or accelerated, erosion."

The U.S. Department of Agriculture has set standards for "tolerable" soil-loss rates. Losses of up to five tons per acre annually are considered acceptable. In some parts of Illinois, intensive farming contributes to more than twice that rate, Olson said.

The fly-ash method is quick, simple, and inexpensive. The techniques and instruments involved are only a soil suspension, a plastic-encased magnet, an eye-dropper, a microscope slide and coverglass, and a microscope. The spherical black, red, and yellow fly-ash particles are easy to distinguish and count under magnification. ■

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The Cover

As the camera's lens fragments and reconstructs the image of the DNA model on the cover, the application of biotechnology offers the possibility of manipulating the real-world counterpart.

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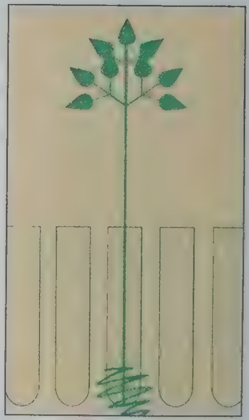
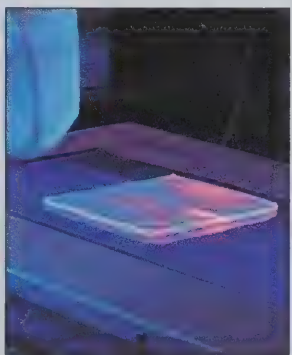
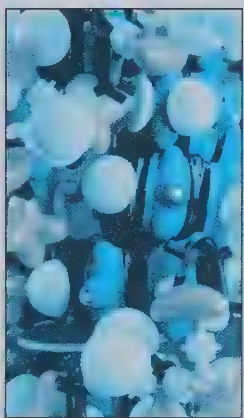


"At a time unlike any in the past, we must envision the future."

Raymond G. Cragele, AES Director, 1978-1983





1991 – Directions – 2001

Biotechnology: A Tool for Change

Throughout history, human beings have feared the wrath of the apocalyptic Four Horsemen: Famine, Pestilence, War, and Death. Those engaged in agriculture have always attempted to balance the years of plenty with those of famine — to grow enough to feed their people even after insects, animals, and bacteria had claimed their shares. The battle was always close-fought: the effort to avoid famine and death was successful only part of the time.

During the twentieth century, science and technology have permitted immeasurable gains in the battle for human survival. Food production at levels far beyond reasonable predictions has resulted from crossbreeding plants or animals for increased vigor and growth, the advent of artificial insemination, and other advances in plant and animal agriculture; losses to pests have been reduced to a fraction of former years; plant and animal diseases have been overcome or reduced; storage of food in a healthful state has improved remarkably; and the life-span of most human beings has been extended significantly.

These gains have not been without problems, however. We are now raising serious questions about the effects of pesticides, preservatives, and growth enhancers on the safety of our food, water, and environment. Issues of decreasing genetic diversity, global temperature changes, and preservation of natural habitats cause us to wonder whether we can provide nutrients for a growing world population while protecting the environment for future generations.

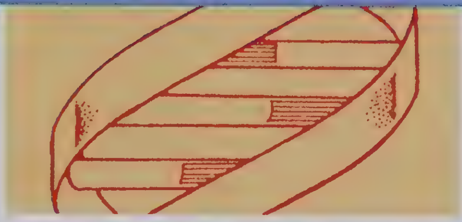
And the needs of the world's people will continue to grow. Today, nearly 5 billion people inhabit the earth. By the year 2030, that number is expected to double.

Recent issues of *Illinois Research* have addressed questions of conservation, sustainable agriculture, and quality of life. This issue is devoted to a new level of science, the molecular level, that could have sweeping effects. Plant and animal biotechnology promises newer, potentially safer solutions to continuing problems. New "biological controls" of diseases and pests could reduce our dependence on antibiotics and pesticides while enhancing our progress in health and conservation. The technologies described in this issue have the potential to increase our quality of life while alleviating or reversing many factors that may contribute to environmental problems.

In the final analysis, however, biotechnology is a tool, a powerful tool with remarkable potential for change. But with biotechnology also come the dilemmas that are always invoked by change. Will it be appropriately regulated? Will it be safe? Is it ethical? What will be its economic impact? Should we take the risks associated with new technologies or eschew their benefits to avoid the unknown? This issue of *Illinois Research* addresses those questions.

John Milton's 1667 classic, *Paradise Lost,* suggested that "fear of change perplexes monarchs." If we can overcome that fear and embrace change, biotechnology can be a useful tool.

W.R. Gomes, Dean of the University of Illinois College of Agriculture



Biotechnology: Issues, Ethics, and Regulations

Tina M. Prow

The public appears to lag behind in its understanding of technology in agriculture, and that concerns those who consider biotechnology to be a tool that could help solve problems ranging from environmental contamination to world hunger.

Issues

"In many ways, the public is still operating with the mentality of the 1970s," said George Kieffer, associate professor at the University of Illinois School of Life Sciences. "They're thinking in terms of creating monster organisms. But we've gotten experience on what can and cannot be done with biotechnology now; and, while those concerns are not to be dismissed as completely irrelevant, they are not the issues of the 1990s."

Public understanding of biotechnology as a science and technology is important because the products of biotechnology — and consequent benefits and risks — are going to affect everyone, Kieffer said.

"Some suggest a third agricultural revolution, in which we won't even grow plants — just cells in tissue culture rather than stems, roots, and leaves," Kieffer said. "That raises a social question about the effect on Third World economies that depend on agriculture."

The agricultural revolution is an extreme example, but represents how society must be involved in determining directions for biotechnology. "What are societal needs? What are the benefits? At what price? These are the kinds of questions we need to think about in the 1990s," he said.

Such questions may account for failure of the genetically engineered bovine somatotropin hormone to gain public acceptance, Kieffer said. It increased efficiency of milk production without improving milk's nutritional value. For consumers, he reasoned, the benefit did not offset their perceived risk from hormones on human health. After losing tomatoes to wilt yet again last year, however, he would find genetically engineered, wilt-resistant tomato plants acceptable.

"We have to ask what we are to gain from this — because there's no such thing as a completely benign engineered organism," Kieffer said.

Part of Kieffer's work is focused on making sure the next generation can understand biotechnology well enough to think through those questions. He helped develop a traveling kit for grades 7 through 12 and conducts workshops for teachers. The goal is to incorporate biotechnology topics into coursework.

Ethics

Scientists, too, are increasingly aware of their responsibility to help the public appreciate the role of science and technology in society, according to Robert Goodman. A former University of Illinois plant pathology professor, Goodman recently resigned from Calgene, Inc., a plant biotechnology company in California, to return to academia, as a professor at the University of Wisconsin–Madison.

Although it takes time and energy, scientists must talk about their work whenever they have an opportunity, Goodman said. He has spoken before legislators, explained proposed field research to communities, presented workshops, appeared on television programs, and been both author and subject of newspaper and magazine articles. He serves on the National Academy of Sciences Research Council's Board on Agriculture, which brings together panels of scientists to counsel government on science policy.

"For too long, we've had a very insular attitude in agriculture, and I think that's how we've come up with a public that has been deluded into thinking that our food supply is somehow pure and pastoral and basically free of technology, when in fact, it is very, very technology intensive," he said.

According to Goodman, biotechnology holds great promise as a tool to preserve and enhance environmental quality on and off farms. And years of plant breeding show that genetics is the most cost-effective, environmentally safe way to address problems that reduce yields.

But without public understanding, acceptance, and support, the role that biotechnology could play in solving environmental and food production problems could be stymied, he said.

"We've got a problem now with a society that doesn't completely understand agriculture; is deeply suspicious of biotechnology; and sees the same companies that sell what they consider nasty ag chemicals investing in biotechnology, or somehow controlling it," Goodman said. "At some level, that suspicious, cynical environment is actually reducing

the interest of the public in investing tax dollars in research."

Annually, the public invests $110 million in agricultural biotechnology through the U.S. Department of Agriculture (USDA). At just 10 percent of the total USDA research budget, that is not enough, according to Alvin Young, director of the USDA Office of Agricultural Biotechnology, Washington, D.C.

Regulation

Young said most university scientists conducting biotechnology research receive federal money. And all scientists deal with the government before research moves from the laboratory to the field. At that stage, they go before regulatory agencies to prove their research is safe.

"We probably, for this new technology, have put more effort into putting in place a regulatory oversight mechanism than we have for any technology in the past," he said.

Young said there is no evidence that biotechnology poses additional risk, but there are uncertainties that concern the public. He pointed to public attitude as a reason for a regulatory system that critics say stifles research. But while biotechnology companies are asking for a more streamlined regulatory system, they are proceeding with field tests. Universities, however, had few of the permits for field testing that were issued in 1989.

The regulatory program may account for some of the lag in field testing, but it is just as likely due to a "funding crisis" in research, Young said. The research community may soon feel even more of a pinch as fewer students choose to become scientists, in part because of funding problems. The end result may be a significant slowdown in what he described as the biotechnology "pipeline."

"You're constantly putting in new ideas coming out of research; those new ideas work their way through; they're evaluated; they turn into products," Young said. He suggested that plant-related biotechnology research is progressing rapidly, and some potential products are in the pipeline. Animal-related biotechnology research, however, has proved to be more complex than scientists anticipated, both in terms of genetics and social issues.

"Most people haven't worried much about transferring genes from one plant to another or transferring a gene from a microorganism into a plant; most people don't care. But when you talk about transferring human genes into fish, for example, some people begin to picture mermaids," Young said.

For scientists, however, the process is one of taking a gene, examining it, and building its synthetic model. Where the public sees human genes and fish genes, scientists see a "commonality" in life that holds potential for such uses as curing or preventing diseases.

"Critics can spend much effort and resources on misinformation, and never be held accountable," Young said. "Public perception is something we have to deal with better. We must try to involve the public in our decision making and public hearings and invite them to see the kind of research we're doing."

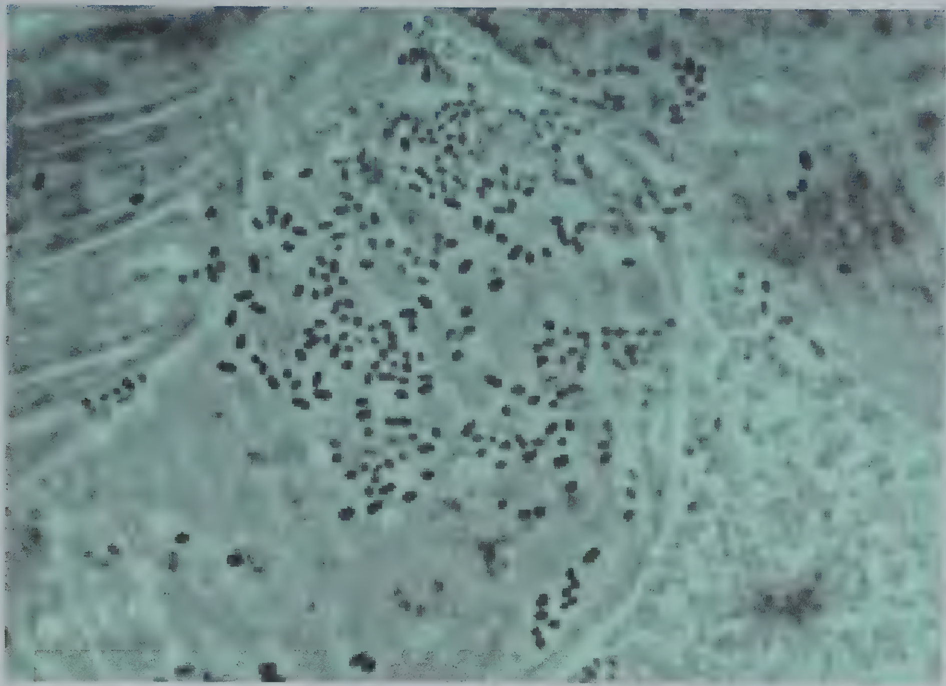
That will happen more often this decade as research is completed for several promising products — disease-, insect-, or herbicide-resistant plants; leaner meats; and more nutritious crops — in the pipeline, he predicted, saying that consumer education will be a critical part of successful commercialization.

With an educated, 1990s viewpoint, then, consumers may see a genetically engineered, wilt-resistant tomato plant as Kieffer does — not as the coming of the killer tomatoes, but as opportunity to grow juicy, flavorful tomatoes.

Tina M. Prow, communications specialist, Office of Agricultural Communications and Education

The Role of Plants in Environmental Toxicology

Michael J. Plewa



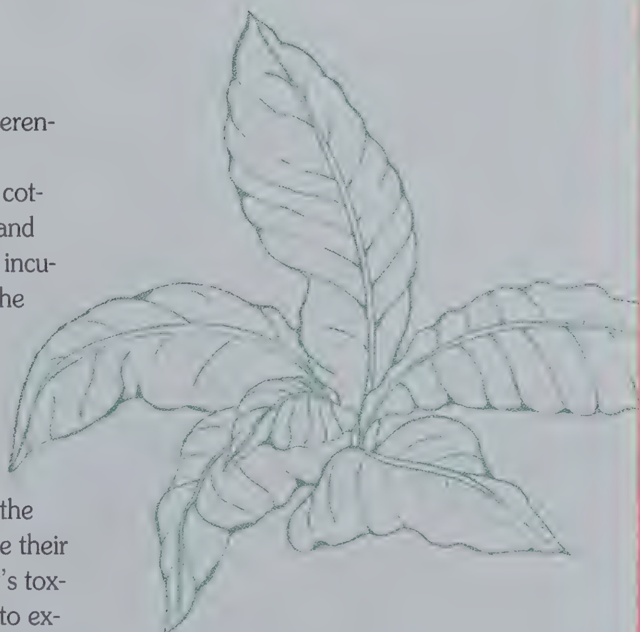
Interaction between Salmonella typhimurium *and tobacco cells. The plant cell is the large kidney-shaped object; the bacteria, the darkly staining small rods. It is the bacteria that are studied for DNA damage after a promutagen has been activated by the plant cells.*

Most of us are concerned about the poisoning of our planet. But even well-informed people may be unaware that plants accumulate, metabolize, and distribute environmental contaminants.

Plants can become a reservoir for these contaminants. Because plants are exposed to environmental pollutants, agricultural chemicals, and naturally occurring toxic agents, plant-activated agents may be introduced into the human food chain. Thus, effects of environmental toxins on plants have a global impact.

Our research uses cultured plant cells to identify promutagens and the biochemical pathways involved in their metabolism. Although promutagens do not damage DNA (the genetic material), they can be biologically transformed into mutagens, agents that produce mutant forms of plants or animals.

Plant and mammalian metabolic systems activate many promutagens. But several environmentally important agents — several s-triazine and thiocarbamate herbicides and plant-growth regulators such as maleic hydrazide — are preferentially activated by plant cells.



The plant cells (cultured tobacco, cotton, carrot, or maize *Tradescantia*) and microbes (bacteria or yeast cells) are incubated together. The plant cells are the activation system and the microbes are the genetic indicator organisms. After the microbes are spread on a selective medium, only mutant cells grow into individual colonies.

Researchers independently study the plant cells and microbes to determine their viability and evaluate each test agent's toxicity. Basic research uses this assay to explain the biochemical mechanisms of plant activation and to analyze plant-mediated antimutagens. Such research could potentially identify chemicals that reduce the toxicity of environmental contaminants.

Michael J. Plewa, professor of genetics, Institute for Environmental Studies, departments of Agronomy and Microbiology

Improving Nutritional Quality of Meat Animals

Floyd K. McKeith

Lean tissue quantity and quality are the major factors in determining the value of meat animals. A continuing goal of the livestock industry is to increase the quantity of high-quality lean tissue; and scientists have used technologies based on genetics, nutrition, and physiology to achieve this goal. Increased consumer demand for lean meat has stimulated the need for technologies to reduce fat and increase lean in meat animals.

Repartitioning agents (beta-adrenergic agonists and somatotropins) are compounds that increase lean content and reduce fat content of meat animals, while improving the rate and efficiency of growth. Although studies on cattle and sheep have also been conducted, the bulk of information available about repartitioning agents involves pigs. Current studies at the University of Illinois and elsewhere are evaluating the potential of these products for the beef industry.

Somatotropins. Somatotropin is a protein normally found in all animals. By augmenting existing somatotropin levels with exogenous somatotropin, swine producers can alter the composition of the meat animal. Studies conducted at the University of Illinois indicate that the fat content of meat animals may be reduced by 25 percent using only 3 milligrams of somatotropin per day. Fat reduction improves nutritional quality of meat animals by reducing fat between muscles, thus improving the yield of consumable lean, and thereby enhancing how consumers view meat products. Results from our studies indicate use of somatotropin causes only small changes in pork's tenderness, juiciness, and flavor. Improvements in meat animal composition were accompanied by increased average daily gain (10 to 20 percent) and increased feed efficiency (10 to 15 percent). Increased availability of somatotropin for research and Food and Drug Administration (FDA) evaluation is due to recent advances in biotechnology.

Beta-adrenergic agonists. These feed additive products result in improvements in meat animal composition and the rate and efficiency of growth. Several different compounds have been developed and evaluated. After evaluating cimaterol and ractopamine in our laboratories, we found that these two beta-adrenergic agonists reduced meat animal fat by 10 to 15 percent, while improving average daily gain and feed efficiency by 10 to 15 percent. No consistent differences in color, firmness, or marbling were observed in the quality of the lean meat produced from these animals.

Although somatotropins and beta-adrenergic agonists are unavailable on the marketplace today, the FDA is evaluating their safety and efficacy for future use in the livestock industry.

Floyd K. McKeith, associate professor of animal sciences

Effects of porcine somatotropin (pst) on American and Chinese pigs at the same age.

Links to Industry

Tina M. Prow

Last year, the University of Illinois released high-oil corn germplasm to industry in a move to further research and bring a potentially high-value crop to farmers.

Du Pont Company and Pfister Hybrid Corn Company gained an exclusive license to develop and commercialize germplasm. They agreed to pay royalties to the University and to fund a collaborative research program that brings together Du Pont and University of Illinois researchers.

The agreement represents the kind of relationship between industry and universities necessary to sustain and renew agriculture, according to John Goss, research supervisor in Du Pont's Stine-Haskell Research Laboratory, Newark, Delaware.

"We're not just an additional funding source," Goss said. "I see our collaboration as part of the Agricultural Experiment Station's effort to do a better job of getting the technology and new products out into the agricultural community.

"And we see having more collaborative relationships with the University as a way we can access other technologies for a fair royalty and research funding commitment, thus allowing us to more rapidly determine whether or not a business opportunity exists and, if it does, to get it to the marketplace."

Traditionally, industry has looked to university researchers for long-term research, cutting-edge discoveries, and new technologies, said Robert Fraley, director of Monsanto's Plant Science and Technology Program, St. Louis. In the biotechnology arena, however, many companies have internal research capabilities and programs of their own.

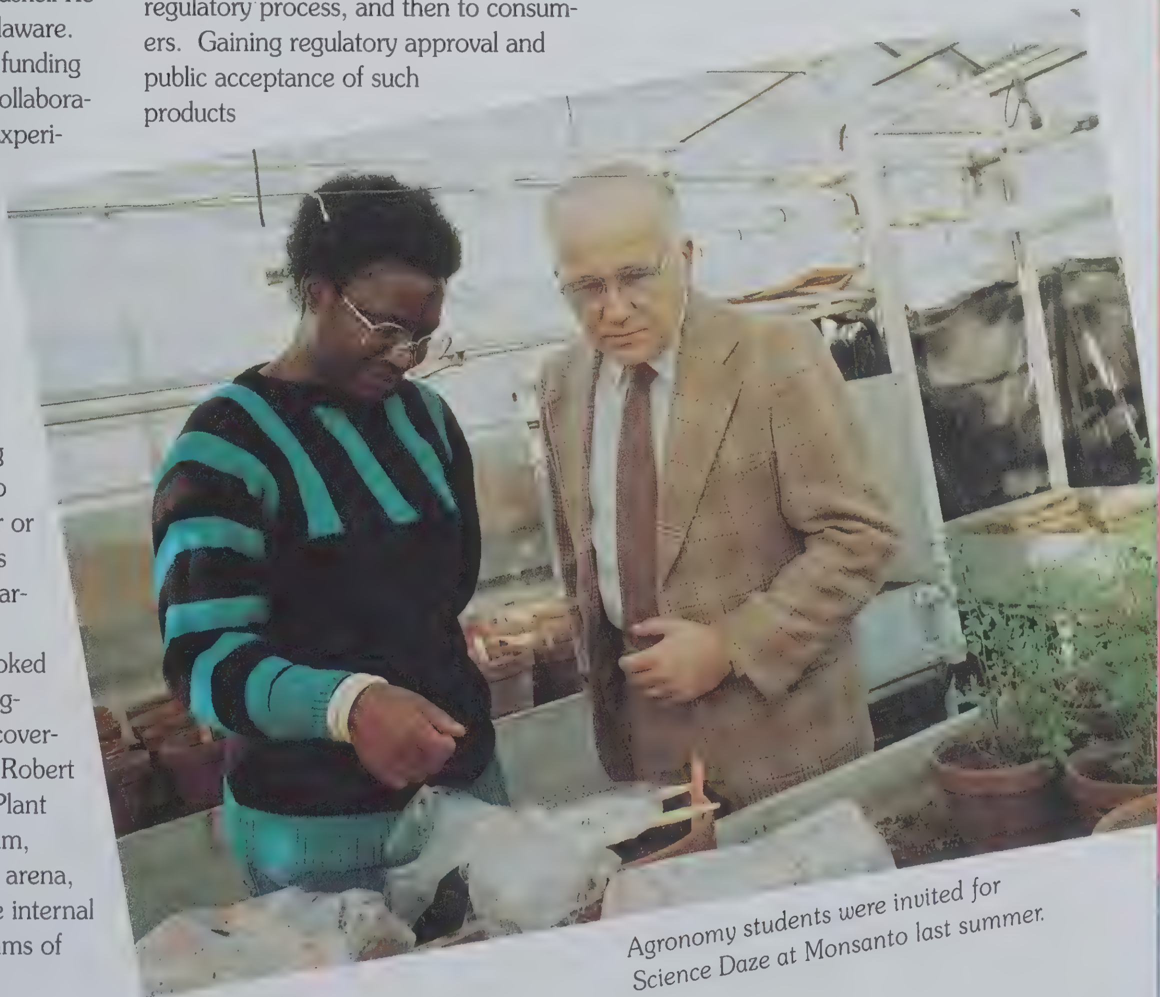
Still, the field is moving so quickly that every research program is dependent on discoveries made in other laboratories, Fraley said. Consequently, collaboration is key to keeping abreast of important developments, maximizing resources, and minimizing risk.

"We're looking for the type of interaction that involves the true exchange between scientists at a university and at Monsanto; where we can bring different pools of expertise together, or different ways of attacking a complicated problem," he said. Monsanto, with an eye toward recruitment and a predicted shortage of scientists, also provides funding for University of Illinois science students and hosts tours to familiarize young scientists with industry research.

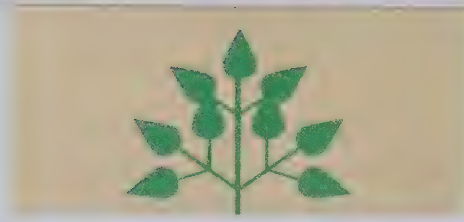
A collaborative relationship will be even more important as biotechnology-based products begin to move from laboratories to field research, through the regulatory process, and then to consumers. Gaining regulatory approval and public acceptance of such products will be a challenge for the entire research community, he said.

"Almost everything I see — whether driven by pure research interest, limited funding that's available, or the magnitude of the commercialization issue — forces a tight linkage in partnership to ensure that we have the best possible chance for success," Fraley said.

Both Goss and Fraley are University of Illinois graduates. Tina M. Prow, communications specialist, Office of Agricultural Communications and Education



Agronomy students were invited for Science Daze at Monsanto last summer.



The Economics of Biotechnology in Field-Crop Production

Lowell D. Hill and Wojciech J. Florkowski

U.S. scientific leaders in the development of agricultural biotechnology can contribute to the economic growth of many countries by commercializing plant cultivars that possess improved genetic characteristics. The potential for increased production and decreased costs has been emphasized by most researchers. But limited resources, the high cost of research, and the undesirable effects of past adoptions of technology have made the public and research community more aware of the importance of evaluating other economic impacts before adopting the new biotechnologies. Additional information is needed about the price and income effects of the increased production and about who gains and who loses market share, income, and welfare — the distributional effects of economic change.

The U.S. Department of Agriculture (USDA) and the Office of Technology Assessment of the U.S. Congress have studied the impacts of agricultural biotechnology and other modern technologies. But most of the studies have avoided the issues of the changes in income and welfare among firms, regions, and economic sectors as the technologies have been commercially adopted.

Policy analysts of economic and social consequences have often relied on qualitative evaluation without quantifying the results. Useful insights into relationships among the important variables can be obtained by quantifying at least those consequences that emanate from direct changes in the quantities produced. Subsequent changes will cause additional adjustments in quantities, and the ripple effects quickly go beyond the capacity of simplifying mathematical models.

The Study

A study was carried out to provide estimates of the welfare changes associated with commercialization of alternative plant biotechnologies. Twelve specific plant technologies were selected for the study: symbiotic changes, new rhizobia strains, altered protein content, virus-resistant varieties, bacteria-resistant varieties, fungus-resistant varieties, insect-resistant varieties, frost-tolerant varieties,

The Kunitz Soybean Variety

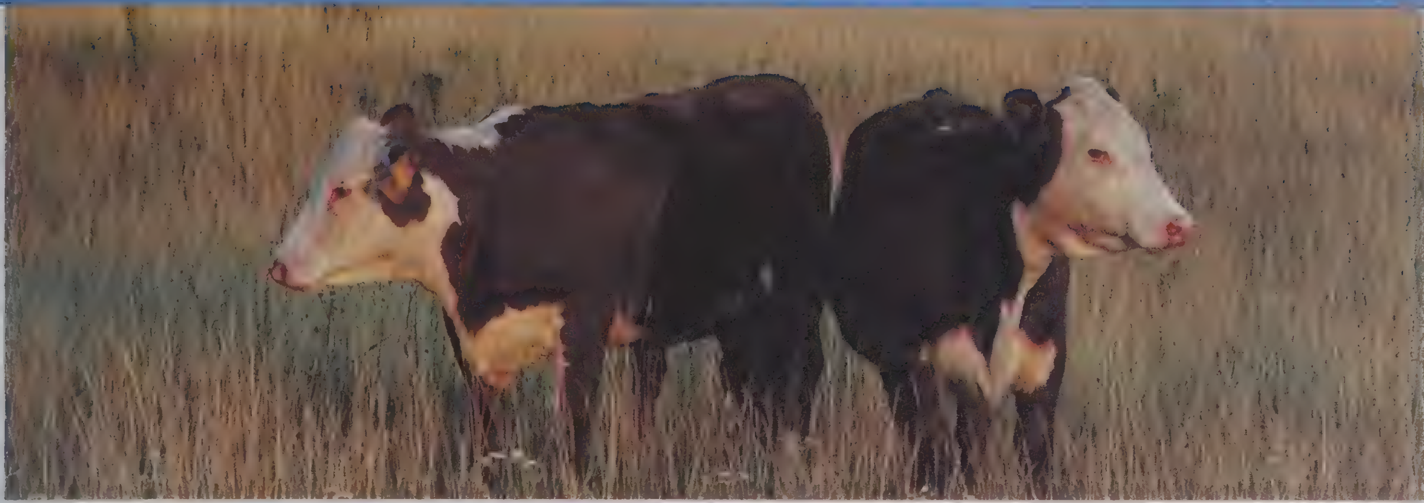
Theodore Hymowitz

In 1917, T.B. Osborne and L.B. Mendel, researchers at the Connecticut Agricultural Experiment Station, demonstrated that unheated, raw soybean meal is inferior in nutritional quality to steam-heated soybean meal. Their research became the foundation for the development of the lucrative soybean processing industry and expanded the potential use of soybean meal as a high-protein feed. Physiologically, the ingestion of raw soybean meal by monogastric animals (for example, poultry or swine) causes pancreatic hypertrophy, a condition in which the pancreas enlarges and ultimately ceases to function.

Moses Kunitz, professor of biochemistry at New York's Rockefeller University, purified and characterized the predominant antinutritional factor in soybean seed in 1945. This factor, a trypsin inhibitor, bears his name and is inactivated during moist heat processing.

In 1968, the author and his colleagues at the Illinois Agricultural Experiment Station began to study the variations in and the genetics of the Kunitz trypsin inhibitor in soybean seed. Thousands of seed samples from the USDA soybean germplasm collection in Urbana, Illinois, and Stoneville, Mississippi, were screened for variation in the Kunitz trypsin inhibitor. Four different trypsin inhibitor (*Ti*) forms were discovered. Three of the forms identified as Ti^a, Ti^b, and Ti^c are distinguishable from one another by banding patterns produced on gels. The differences are due to amino acid substitutions in the protein. Genetic studies have revealed that the three forms are controlled by a co-dominant multiple allelic system at a single locus. All major soybean varieties grown in the United States contain the Ti^a form.

The fourth form, found in soybean germplasm samples PI 157440 and PI



herbicide-tolerant varieties, heat-tolerant varieties, plant growth regulators (PGRs), and ice-retarding bacteria. The principal criterion for selection was the probability of rapid commercial adoption.

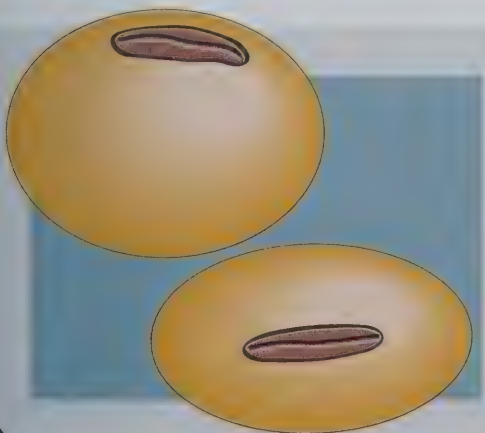
The effects of these alternative biotechnologies on major crops were measured for ten regions of the country, covering both nonirrigated and irrigated land. The model used published statistics on the cost and quantities of inputs applied per acre for nine row crops: barley, corn, cotton, oats, peanuts, rice, wheat, sorghum, and soybeans.

Welfare is measured by consumer and producer surpluses. The analysis gives information about the potential regional reallocation of agricultural land to alternative uses and about welfare gains to consumers. The models used in the analysis demonstrate long-term, aggregate effects of each new technology, assuming full adoption. Impacts of each technology were examined independently of the other eleven; no simultaneous adoption of two or more technologies was allowed in the model.

Model Solutions

Model solutions show a decrease in total acreage used for the production of the nine crops included in the analysis after the introduction of biotechnology. Irrigated and nonirrigated land withdrawn from production is located in the Delta and Southeast and, to a smaller extent, in the Appalachian, Mountain, and Northern Plains regions. The affected regions represent a range of different climates and growing conditions that offers a potential for developing specialized agricultural production.

The decrease in acres planted to row crops resulting from yield-increasing technology will slow the degradation of the environment. Replanting the withdrawn land with perennial or cover crops would lower soil erosion. The technologies that would cause the largest relocations of crops and prove beneficial from the standpoint of soil protection are the use of PGRs, heat-tolerant cultivars, bacteria- and virus-resistant plants, and cultivars with altered protein content.



196168, lacks the Kunitz trypsin inhibitor. The absence of the protein is inherited as a recessive allele to Ti^a, Ti^b, and Ti^c, and has been designated *ti*. Although other inhibitors may be present in the seed of PI 157440 and PI 196168, all experimental evidence from genetic, biochemical, and molecular studies indicates that the seeds of the two accessions lack the Kunitz trypsin inhibitor.

The Kunitz soybean variety was developed by backcrossing and is the progeny of an F_2 plant selected from the fifth backcross, Williams 82(6) × PI 157440. Kunitz is similar to Williams 82 in all visible traits such as white flowers; tawny hairs; tan pods; and shiny, yellow seeds. Kunitz is resistant to many races of phytophthora rot, bacterial pustule, leaf spot, and powdery mildew. Kunitz is also similar to Williams 82 in yield performance, and in the seed's protein and oil content.

The advantages of the Kunitz soybean variety over other commercial varieties are as follows:

- Farm-grown soybeans can be fed directly to swine in their finishing rations.
- Kunitz can replace as much as 50 percent of the heated soybean meal in chick rations.
- Processors can save about 25 percent in energy costs in processing Kunitz soybeans.
- Kunitz can be exported to those countries lacking soybean processing facilities.
- Kunitz is an excellent raw product for companies making soy-based foods for babies.

Theodore Hymowitz, professor of plant genetics, Department of Agronomy

The four technologies most beneficial to society, as measured by the change in total surplus (consumer plus producer returns), are cultivars with altered protein content, virus- and bacteria-resistant cultivars, and cultivars responding to PGRs. This ranking was largely influenced by the size of consumer surplus, which was the highest for these technologies. All biotechnologies negatively affected producer surplus — the smallest effect being that from commercialization of cultivars with altered protein content, and the largest being the effect of widespread use of PGRs. Assuming no change in demand, a larger volume of commodities causes lower gross income in the aggregate as a result of a percentage decrease in prices that is greater than the percentage increase in output. In the cost data used in this model, the new technologies did not sufficiently reduce the cost of production to compensate for lower prices.

Thus, the introduction of new technologies decreases aggregate farm income, as measured by producer surplus. Realized income on an individual farm may decrease or increase, depending on market price, skillful application of the new technologies, and benefits of early adoption. The reduction in farm income shown by the models is the direct result of increased supply under the assumed price elasticities. The negative effects on the producer sector can be alleviated by expanding demand, finding new uses, and controlling supply through government action; by transferring income from consumers, processors, and other groups that benefit from lower crop prices; and by lowering production costs.

Aggregate income of the agricultural sector in each region will be affected differently as a result of differences in crop rotations, importance of certain crops in a region, and the different yields and costs of production in each region. For example, a larger portion of total farm income will go to producers in the Midwest who have a comparative advantage in production of row crops.

Conclusion

The impact of biotechnology illustrates a polar case of a long-term full adoption of twelve separate technologies applied to a limited number of field crops. The information about potential future land allocation and welfare changes contributes to the constantly expanding pool of knowledge concerning predictions of the impact of agricultural technology.

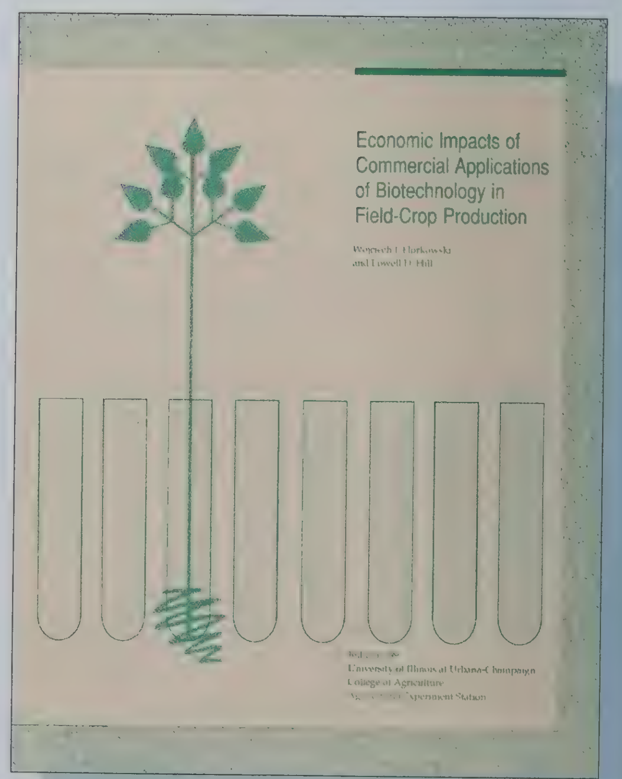
Specifically, this study indicated to agricultural research administrators the perceived probabilities of developing different biotechnologies and economic impact of their commercialization. Allocation of research funds may be determined not only by the short-term success in developing a technology but also by its long-term welfare effects. Welfare effects, in turn, may not be limited to the easily quantifiable changes in total surplus. These may also include the effect on quality and sustainability of natural resources, such as unpolluted water or uneroded soil. Some of the biotechnologies considered in this study would lower pesticide use and withdraw land from agricultural production.

Policymakers may use the information from this study to formulate policy goals that would make the necessary adjustments easier and to fully explore benefits offered by the use of biotechnology in crop production. For example, programs for alternative land use or economic programs that sustain rural community growth may be needed as agriculture diminishes in importance.

For farmers and farm groups contributing funds for research and market development, the results of this study suggest paying more attention to the demand for agricultural crops. Traditional food, feed, and fiber use of grains, oil crops, and cotton could be augmented by industrial uses of crops. Industrial use of agricultural crops would change the demand structure and create new markets. Research funds applied toward research on new uses of commodities and on feasibility studies of new markets could make biotechnology work to the benefit of farmers.

This article is excerpted from a recent Station bulletin, Economic Impacts of Commercial Applications of Biotechnology in Field Crop Production. *Bulletin 799 is available for $3 from the Office of Agricultural Communications and Education, (217)333-2007.*

Lowell D. Hill, L.J. Norton Professor of Agricultural Marketing, Department of Agricultural Economics, and Wojciech J. Florkowski, assistant professor of agricultural economics, University of Georgia and Georgia Experiment Station, Griffith, Georgia



Biotechnology of Grain Quality Traits

Alan L. Kriz

Alan Kriz examines laboratory corn plants.

The value of grain crops accrues from the types of compounds that normally accumulate during the important stage of seed development commonly referred to as grain-filling. During this period, compounds such as protein, starch, and oil accumulate to high levels as part of the natural seed growth process. Over the past century, plant breeders have developed new varieties of seed crop plants that allow for increased production of grain components. Advances have been made not only with respect to increasing the starch, oil, and protein content in the seed but, in some cases, to the quality of these components as well. For example, naturally occurring genetic variation has allowed maize varieties to develop with modified starch content and increased or altered oil content.

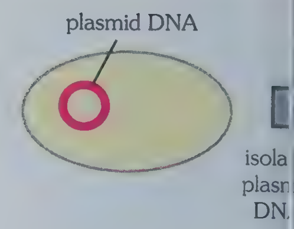
An important aspect of grain quality that is being studied at the University of Illinois Department of Agronomy involves the nutritional characteristics of seed proteins. Seed proteins of any given crop usually do not contain sufficient quantities of certain amino acids that are essential in the diet of humans and other monogastric animals. Because cereals are usually deficient in lysine and tryptophan, and legumes are deficient in the sulfur amino acids methionine and cystine, a mixture of cereals and legumes is used to provide a balance of amino acids in the diet.

Nutritionists have specified those aspects of grain protein quality that are most desirable, but to date the development of corn or soybeans containing a satisfactory balance of amino acids has not been possible. Plant breeders have had only limited success in improving the nutritional quality of seed proteins, primarily because genes encoding the seed storage proteins with high levels of essential amino acids do not normally exist in any given species. Modifying the genes that encode seed proteins by genetic engineering may therefore be an ideal solution to the problem of nutritional quality.

A general approach to enhancing grain nutritional quality involves altering the proteins in the grain that normally contain the bulk of the amino acids. Specific genes from plants are readily isolated. Using routine laboratory techniques, the DNA sequence, or program, of those genes is then altered to create a new gene sequence that encodes a protein of desirable nutritional quality. For example, over a few months, we have been able to increase the lysine content of a specific corn grain protein by 50 percent, and the tryptophan content of that same protein by 700 percent. The extent to which the seed tolerates such altered genes remains to be seen.

However straightforward the genetic engineering approach, certain problems must be overcome to apply successfully this technology to the particular problem of improving seed protein quality. Recombinant DNA clones are routinely isolated that correspond to genes that encode specific proteins. These clones may be easily manipulated so that they contain appropriate instructions for desired amino acids. The major limitation in implementing this technology now is the lack of efficient genetic transformation systems for corn and soybeans. But recent advances in this area indicate that it will soon be possible to use biotechnology to genetically manipulate grain protein quality in these major crop species.

Alan L. Kriz, assistant professor of crop molecular genetics, Department of Agronomy



Microbial Biotechnology

Hans-Peter M. Blaschek, Roderick I. Mackie, and Paul D. Shaw

Microorganisms have been exploited for their specific biochemical and physiological properties from the earliest times for baking, brewing, and food preservation and more recently for producing antibiotics, solvents, amino acids, feed supplements, and chemical feedstuffs. Over time, there has been continuous selection by scientists of special strains of microorganisms, based on their efficiency to perform a desired function. Progress, however, has been slow, often difficult to explain, and hard to repeat.

Recent developments in molecular biology and genetic engineering could provide novel solutions to long-standing problems. Over the past decade, scientists have developed the techniques to move a gene from one organism to another, based on discoveries of how cells store, duplicate, and transfer genetic information.

Recombinant DNA technology has vast potential benefits, and agriculture is a prime area where these modern techniques will have greatest impact. Recombinant DNA techniques may provide us with disease-resistant crops, feed crops with higher nutritional and digestive quality, improved vaccines for animal health, hormones to enhance milk and meat production, enzymes to improve digestion of feedstuffs, new ways to clean up our environment, and more efficient methods to produce chemicals.

Fermentation Biotechnology

Until recently, fermentation processes depended on a few types of raw materials (substrates) and on available strains of microorganisms. But now microbes can be genetically manipulated to function more efficiently and to use a wide variety of substrates. As these microbes are re-engineered and their fermentation capabilities fully exploited, we rapidly near the day when chemicals can be produced economically and naturally.

The development of any successful industrial process ultimately depends on efficiently converting the substrate to a highly concentrated end product. Because of the potential for commercial success, research in the Department of Food Science is focused on the acetone-butanol-ethanol (ABE) fermentation. To make the ABE fermentation economically viable, several problems must be addressed.

The first problem relates to how product toxicity leads to low concentrations of butanol in the fermentation broth. The microorganism *Clostridium acetobutylicum* is intolerant of low concentrations of butanol; as little as 1.3 percent inhibits growth and fermentation. Increasing the butanol from 1.3 to 2 percent in the fermentation broth decreases the energy required for product recovery by 50 percent.

Another problem is the limited spectrum of substrates that can be used by the microorganism.

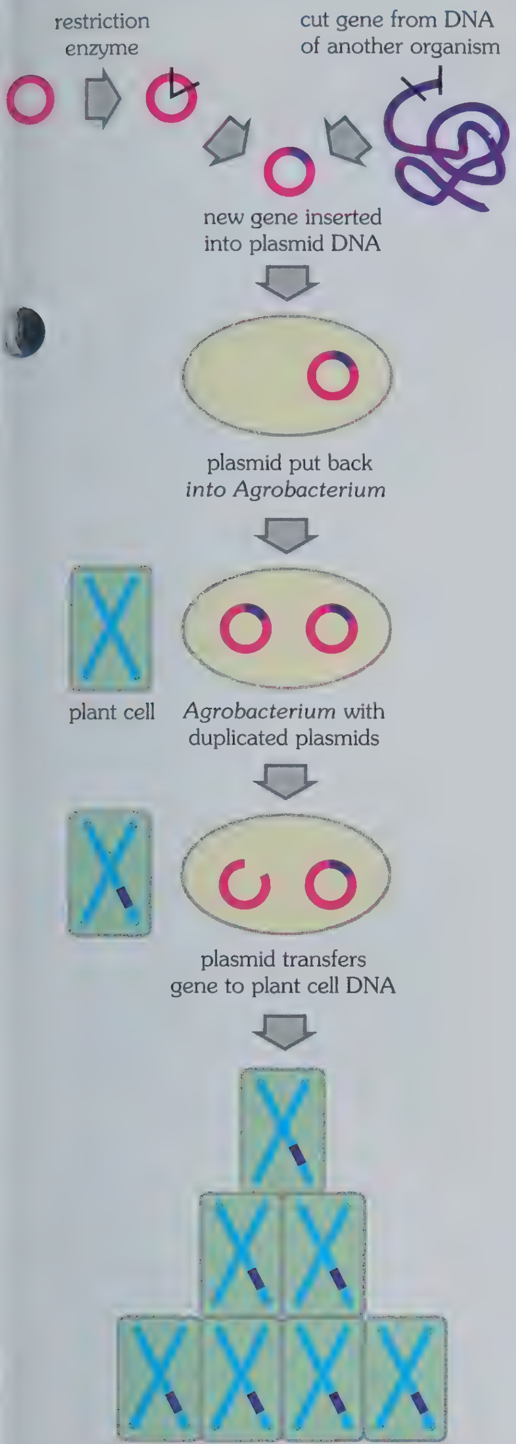
Work in Hans Blaschek's laboratory develops tailor-made strains of *C. acetobutylicum*, a microorganism that tolerates butanol and uses starch or cellulose to produce butanol. The approach involves cloning genes capable of hydrolyzing cellulose (called cellulases), and starch (amylases) into *C. acetobutylicum*. Although the application of genetic engineering techniques to *C. acetobutylicum* is still in its infancy, the potential for improving the fermentation characteristics of this microorganism is great. This technology should allow for improvements in the sequence of enzyme-catalyzed reactions, end-product tolerance, and the actual enzyme systems of this microorganism.

Potential benefits to the food industry include a practical and economical means to dispose of agricultural wastes and processing by-products. Furthermore, biomass-derived chemicals should help reduce our dependence on fossil fuels, the current source of these chemicals.

Rumen Microbiology

Ruminant animals (cattle, sheep, goats, and many other animal species) are nutritionally dependent on the activity of microorganisms present in the rumen. This dependence is based on microbial activity that degrades plant fiber, uses nonprotein nitrogen (NPN), and transforms phytotoxins or toxins produced by plants.

The approach being taken in the Department of Animal Sciences by Bryan White is to improve ruminal fiber digestion by amplifying the cellulose-hydrolyzing capabilities of predominant cellulolytic bacteria in the rumen, the Ruminococci. The complex cellulase enzyme system of *Ruminococcus flavefaciens* FD-1 has been studied extensively. Three synergistic cellulase components (exo- and endo-



As cell divides, each daughter cell receives the new gene.

Source: Adapted from *Introduction to Plant Biotechnology*, K. McPheeters, Vocational Agriculture Service (1989).

glucanases) have been purified to homogeneity, characterized biochemically, and used to elicit specific antibodies for immunological studies on enzyme location and function. These results suggest that the β-glucanases of the Ruminococci have more bond specificity than sugar specificity and probably play an important role in cell wall hydrolysis, a chemical process of decomposition.

Molecular cloning experiments of cellulases from *Ruminococcus flavefaciens* FD-1 have identified at least four different genes encoding for endoglucanase activity. DNA sequence analysis in progress will provide vital information on the regulatory and mechanistic elements of cellulose hydrolysis by these rumen bacteria.

Thus far, gene transfer systems have not been established in ruminal bacteria. One of the barriers is the presence of restriction-modification systems that cause extensive cutting of introduced DNA. Several restriction-modification systems have been identified in the Ruminococci and our understanding of their activity will potentially result in successful DNA transfer and allow the reintroduction of cloned (modified) genes back into the original host. Both the potential benefits and the problems involved in this research are great. Before this technology becomes a reality and genetically engineered organisms can be reintroduced into the rumen to enhance plant fiber degradation, however, a sustained and substantial commitment will be required.

Plant Pathogens

The roots and aboveground parts of a plant growing in soil are in constant contact with thousands of different microorganisms, most of which do not affect the plant in any easily observable way. Although bacteria capable of invading plant tissue and causing disease are rare, many of them are closely related to the harmless bacteria also found in soil and on plant surfaces. The plant pathogens, disease-causing agents or organisms, thus have unique properties that could be useful in devising ways to control the diseases they cause.

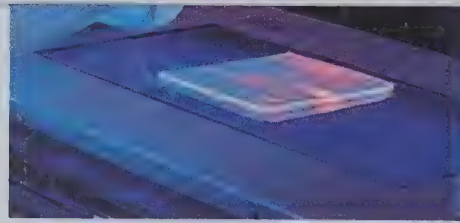
One species of bacteria being studied in Paul Shaw's laboratory is *Pseudomonas syringae* pathovar *tabaci*, one of about 50 different pathovars of that bacterium that cause diseases on many plants from apples to zinnias. The strain under study infects green beans and tobacco, causing a disease called "wildfire," due to the rapidity with which it can spread in a field.

A second species of bacteria is *Xanthomonas campestris* pathovar *glycines*. *X. campestris* also causes disease on many plants, but pathovar *glycines* attacks only soybeans and causes bacterial pustule, in terms of yield loss, one of the most serious bacterial diseases of soybeans in Illinois.

The initial objective of the research was to identify genes responsible for making the bacteria plant pathogens. The techniques of molecular biology are used to isolate pathogenicity genes from the bacterial chromosome. Although eight such genes have been found in *P. syringae* and more than 16 in *X. campestris*, it is not likely that they represent all the pathogenicity genes present in the bacteria. Many genes are translated into proteins or molecules responsible for carrying out most cellular functions. The next step, therefore, was to determine if the isolated genes had the potential to encode proteins. The four genes examined thus far appear to have that capability, and one likely candidate for a pathogenicity protein has been detected.

The ultimate objectives of the research are to determine the functions of the proteins and to define their roles in pathogenesis or disease origin. For example, one of the potential proteins from *X. campestris* is probably present in the membrane that surrounds the bacterium and might therefore be involved in transporting nutrients or other compounds into or from the bacterial cells from culture media, intercellular plant fluids, water on the plant surface, the aqueous milieu in the soil or wherever the organism is growing. Other pathogenicity proteins will be characterized so that they can become targets for disease control measures.

Hans-Peter M. Blaschek, professor of food science; Roderick I. Mackie, visiting professor of animal sciences; and Paul D. Shaw, professor of biochemistry, Department of Plant Pathology



Animal and Plant Genomic Research

Lawrence B. Schook and A. Lane Rayburn

The current emphasis of biotechnology in animal and plant agriculture is the need to identify and manipulate genes affecting disease resistance, growth, and other economically important traits (for example, seed-oil content or fat content of meat or milk). By constructing "genetic road maps" for major livestock and food crops, researchers can assist producers in providing improved and safer food for world markets. Genomic research also provides tools for applying this information through improved breeding programs, direct manipulation of genes through growth promotants, and — through genetic transformation — the ability to create unique new animals and plants resistant to diseases and adaptable to variable climate conditions.

Approaches and Tools

Research initiatives in both animal and plant genomic research have provided new methods and tools for using standard principles of breeding and selection. Domestication of animals and the development of hybrid crops have served us well. Our understanding of the organization of animal and plant genomes (genetic composition) has increased greatly in recent years. Our interest in learning about the human genome has provided a strong scientific base for agricultural efforts.

Several approaches are used to map, identify, and characterize genes. Linkage mapping uses crosses to locate genes relative to others in progeny. Restriction fragment length polymorphisms (RFLPs) play an integral role in creating genetic linkage maps (see related sidebars by Dudley and Rocheford). In RFLP maps, special enzymes are used to cut the deoxyribonucleic acid (DNA) of an organism into smaller pieces. The patterns revealed by probing the cut DNA provide information that can be used to determine linkage of traits to specific RFLP patterns. Establishing such linkages allows both animal and plant researchers to more efficiently develop organisms of increased agricultural performance.

Another method to identify and characterize genes is to physically identify their location on chromosomes and to clone genes using recombinant DNA technologies. The use of recombinant DNA techniques is extremely important in constructing novel genes to enhance and control the proteins encoded by them, which affect production traits.

Benefits to Producers and Consumers

Lawrence Schook and Harris Lewin, Department of Animal Sciences, organized a USDA-supported international conference, "Mapping Domestic Animal Genomes: Needs and Opportunities," during April 1990. Participants represented international industry, governments, universities, and research institutions. A major recommendation was to develop genetic linkage maps for the agriculturally important animal species, maps to explore and use the genes for disease resistance, reproduction, and growth traits.

Currently, the Department of Animal Sciences has several research projects funded by the USDA, the National Pork Producers Council, and various international agencies. Lewin is developing strategies and techniques (RFLPs of individual sperm) to detect major genes affecting growth, lactation, and development in cattle. His group is one of the first to demonstrate how genomic markers can be used to select animals for faster growth and meat properties.

James Robinson and Roger Shanks are using new molecular approaches to identify dairy cattle that carry a recessive gene responsible for embryonic death. Scientists collaborating in the colleges of Agriculture and Veterinary Medicine focus on providing safer food by understanding the genetic basis of salmonella food poisoning and how the bovine leukemia virus affects milk production.

The recently imported Chinese pigs have stimulated new research activities. For example, a multidisciplinary team (Schook, Lewin, David McLaren, and Matthew Wheeler) has initiated a long-term program to determine the genetic basis for carcass composition and reproductive prolificacy in swine.

An international program headed by David Thomas is using genomic research methodologies aimed at improving the prolificacy of sheep.

University of Illinois researchers are also providing leadership in developing new techniques that unravel the mysteries of inheritance. Rohan Fernando has developed statistical models for using

Graduate student Suzanne Boussard prepares a DNA sample for electrophoresis. Electrophoresis is the movement of molecules through a fluid or gel under the action of an electric current.

genetic markers to assist in animal selection to increase rates of genetic improvement. Lewin, Wheeler, Carol Whetstone, Marite Ivanova, and Schook are developing strategies to manipulate genetically and select embryos that will result in cattle and pigs with enhanced growth, meat quality, and disease resistance.

In the last decade, major advances in molecular biology have permitted the incorporation of novel genetic material into plant species. Cultivated plant species will realize the promise of this technology through the addition of genes that will result in the decreased use of pesticides, increased pest resistance and nutritional value, enhanced adaptation to environmental stress, and alternative uses for the plants.

Dudley and Rocheford have used genetic road maps to identify genes controlling quantitative traits of economic importance in corn. In crops such as soybeans where molecular maps are not yet fully developed, Ted Hymowitz and Lila Vodkin are providing valuable information for developing these maps.

Genome mapping studies, while important to genetic manipulation, are not the only ongoing genomic research at the University of Illinois. Researchers are working to improve transformation and regeneration of specific crop species (Jack Widholm), to identify and manipulate genes to target for transformation (Alan Kriz), and to optimize the expression of genes introduced into plant species in both the amount of product and which tissues are producing the

product during plant development (Steven Farrand and Angus Hepburn).

Critical to the manipulation of crop plants is increased understanding of the plant genome. Aided by the facilities of the Cell Sciences Laboratory of the Biotechnology Center, A. Lane Rayburn is investigating the organization of genetic material in plant chromosomes and nuclei.

Future Perspectives

The continued development of scientific tools used in genomic research will help the U.S. agricultural community remain competitive in world markets and in position to enter new and specialized domestic and foreign markets. Researchers at the University of Illinois are at the forefront of genomic research, and the new Plant and Animal Biotechnology Laboratory will provide state-of-the-art facilities to maintain this leadership role.

Lawrence B. Schook, professor of molecular immunology, Department of Animal Sciences, and A. Lane Rayburn, assistant professor of cytogenetics, Department of Agronomy

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Molecular Identification

Charles R. Vossbrinck

Most of us, scientists included, have the illusion that the degree of detail with which we have identified a living thing is appropriate. For some, it is enough to know that they have trees and flowers growing in their front yards; for others, it is important to recognize whether the trees are oaks or elms and the flowers are daffodils or chrysanthemums.

Today's technology allows us to identify any living thing to any level of precision — by using a single cell. This technology uses molecular probes that bind only to the DNA of targeted organisms, is based on gene amplification that multiplies a millionfold the DNA of interest, and involves comparing specific pieces of DNA between organisms.

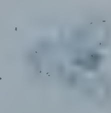
Molecular identification has two important advantages over conventional techniques of microscopic examination. Identification can be made using a very small amount of material, and is much more accurate than with previous methods — a species, a population, or even an individual can be identified.

Applications. Several applications of this technology are already being used. Individual humans have been identified from a single hair, a drop of blood, or a scraping of skin. Such forensic information has already has been used as conclusive evidence in cases of paternity, homicide, and sexual assault.

Gene amplification has great application in the area of medical diagnostics. Commercial tests are now available to identify, with precision, such disease-causing bacteria as *Legionella* (Legionnaire's disease), *Mycoplasma pneumoniae* (pneumonia), and *Neisseria gonorrheae* (gonorrhea). And in the food industry, bacterial diagnostics, also based on gene amplification, includes tests for *Salmonella*, *Staphylococcus*, and *Listeria*, which all cause food poisoning.

Current research. Research in the Office of Agricultural Entomology at the University of Illinois focuses on both the identification of insects and of the microorganisms associated with insects. Comparison of pieces of DNA has already been used to determine the evolutionary relationships between a group of flies, the Calypterates. This group includes many agricultural and medical pests, such as horn flies (pest of dairy cattle), face flies, tsetse flies (which transmit African sleeping sickness), flesh flies, blow flies, bot flies (parasites of horses and cattle), and house flies.

With a grant from the National Institutes of Health, we are examining opportunistic parasites of humans who have compromised immunological systems. For example, with their impaired immunological defenses, many AIDS patients have become infected with microsporidia, parasites that ordinarily cannot attack humans. We use molecular identification techniques to determine the origin of these microsporidia or which organisms transmit them to humans, and how to prevent their transmission.



Another project uses genetic probes to identify the areas of the southern United States that corn earworms and corn leaf aphids come from and determine if these insect pests are carrying transmissible plant diseases. Unable to survive Illinois winters, they migrate to Illinois from the south each spring. We hope that the information obtained will eventually allow us to make early crop control recommendations.

Other projects under way include the differentiation of populations of corn rootworms and of insect pests of livestock. Future applications of molecular identification are limited only by need, ingenuity, and imagination.

Charles R. Vossbrinck, assistant professor of agricultural entomology

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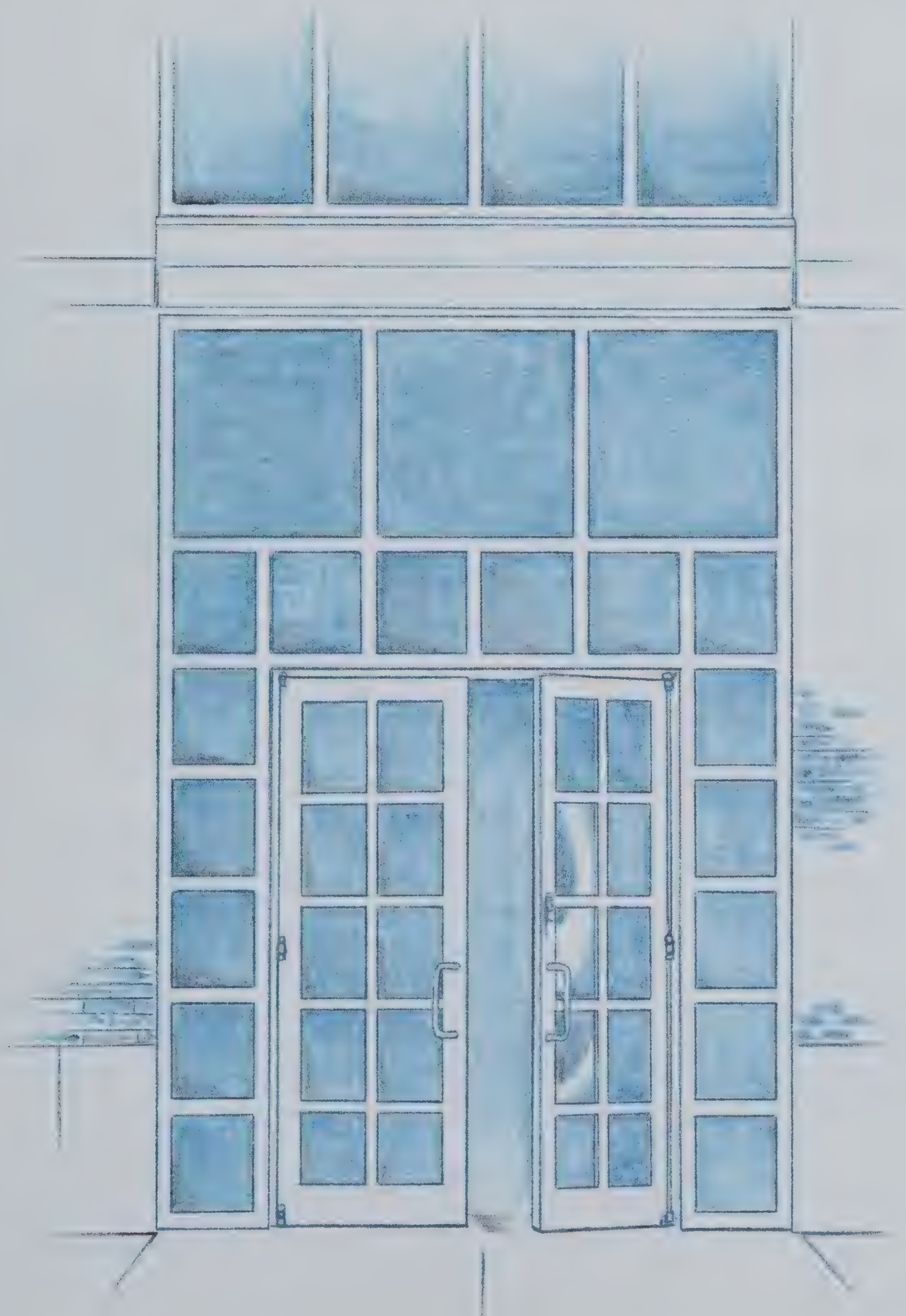
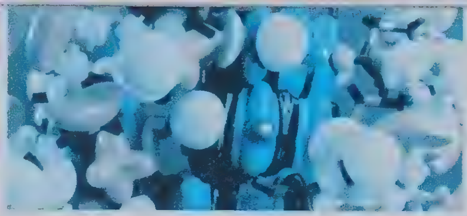
The Plant and Animal Biotechnology Laboratory

University of Illinois at Urbana-Champaign

Dedication, September 21, 1991





A Saga of the Plant and Animal Biotechnology Laboratory

Donald A. Holt

Volumes could be written about the historical roots of the Plant and Animal Biotechnology Laboratory (PABL). Time and space, however, prohibit me from telling the whole story about the farmers, agribusiness people, legislators, scientists, administrators, and alumni who played important roles in the building's development. So I simply offer a personal recollection of events related to the PABL.

Awakenings

All that was known about DNA (deoxyribonucleic acid) in the 1950s, when I was a student at the University of Illinois, was that it was an important constituent of genes and chromosomes and had something to do with heredity. In 1956, English scientist James Watson published *The Double Helix*. This now-famous book describes how he and Francis Crick determined the unique structure of DNA, thereby laying the foundation for the modern science of molecular genetics.

Another important development was tissue culture, the ability to keep individual tissues, such as leaf, root, or muscle tissue, separated from organisms, alive and functioning in various media. Scientists were already realizing that unique tissue and cell lines could be selected in tissue culture, just as unique plants and animals are selected in typical plant and animal breeding programs.

As a Ph.D. candidate at Purdue University in the early 1960s, I became aware that molecular genetics was a rapidly expanding field of research. Later, as a Purdue faculty member, I saw that scientists around the world were learning more and more about DNA — how the structural and functional specifications of an organism are encoded in DNA, and how this information is expressed in the growth and development of the organism.

Needs and Opportunities

A vigorous institutional discussion of biotechnology was underway at UIUC when I returned to head the agronomy department in the spring of 1982. More conservative scientists urged caution, correctly judging that the first practical applications of agricultural biotechnology were at least a decade away. Others urged the institution to move aggressively into biotechnology, arguing that at best it would take a decade to build the infrastructure (people, buildings, facilities, equipment, and support services) required to maintain and improve the University's position of international leadership in biotechnology. Social, legal, and philosophical dimensions of biotechnology were hot topics of discussion.

In the agronomy department, we were acutely aware of the need for space. For example, the program of one senior scientist grew to include 20 postdoctoral and graduate students, technicians, and others. Even when we assigned that scientist a suite of laboratories extending from the east to the west side of Turner Hall, only six feet of bench space was available to each person in the program!

We asked what would happen if each of the research programs in Turner hall grew to that size, and found there would be space for only 20 programs, instead of the 80 housed in the building at that time. We definitely had hit the wall. Similarly crowded, inadequate facilities limited programs in other departments. Among other problems, the colleges of Agriculture and Veterinary Medicine lacked the sophisticated animal care and isolation facilities required for biotechnology research.

Charting a Course

By the summer of 1982, we were charting the University's course in biotechnology. A state-supported initiative provided two essential support programs — the Recombinant DNA Laboratory and the Cell Science Laboratory, then housed in Morrill Hall. Several new molecular geneticists were employed, including six in the College of Agriculture.

During this time of institutional soul-searching, the University's legislative liaison people were kept busy relaying ideas about emerging biotechnology needs and opportunities to members of the Illinois congressional delegation and their assistants. At the same time, it helped that interest in biotechnology was increasing, both nationally and internationally.

The Rising Tide

In the early 1980s, our efforts to build a strong base of agricultural biotechnology research were rewarded as we successfully competed for outside support.

By the end of 1982, the University had negotiated grants totaling over $1 million with Agrigenetics Corporation, a venture capital firm interested in supporting innovative molecular-genetics and tissue-culture research underway in the agronomy department. With these and other public and private grants, the agricultural biotechnology program was rapidly expanding.

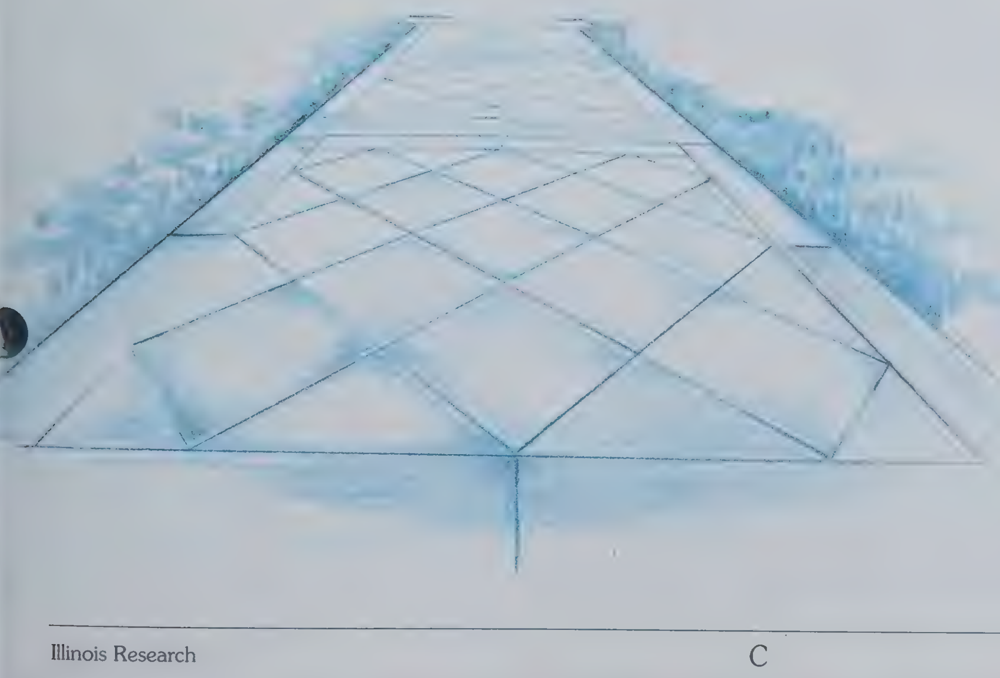
In 1983 the College of Agriculture, in cooperation with scientists in the School of Life Sciences, competed successfully with over 950 public and private institutions and agencies for a Center of Excellence in Crop Molecular Genetics and Genetic Engineering, funded by the Standard Oil Company of Ohio. Success in this competition focused national and international attention on the University of Illinois biotechnology program.

Decisive Moves

Early in 1983, we received word that Congressman Ed Madigan of Illinois was interested in helping us develop a biotechnology research center. We quickly hand-carried a short document to Washington describing "A Proposal for an Agricultural Biotechnology Research Center at the University of Illinois." This was the first of three key documents in which we articulated the dream of the Plant and Animal Biotechnology Laboratory.

In May 1983, Congressman Madigan talked with us about potential federal funding for a major facility. As minority leader of the House Agriculture Committee, he wanted the project to benefit the nation's farmers, agribusiness people, and consumers.

During the meeting, we described the enormous potential of this proposed facility to the nation's food and renewable resources system. We explained that we needed 100,000 square feet of assignable space in laboratories, offices, and support facilities. Given the technical complexity of the proposed building and its programs, we estimated the cost at $300 per square foot, or $30 million dollars. Congressman Madigan said federal funding of the project was possible, and he set in motion the political process that would lead to the Plant and Animal Biotechnology Laboratory.



The Dream Becomes Reality

Our second key document in November 1985 contained the first detailed description of the facility and its potential research programs. "In Quest of Excellence — A Plant and Animal Sciences Research Center" provided a budget for the facility and a list of the Food for Century III projects that were strong evidence of the State of Illinois's commitment to agricultural research.

Questions being raised on the floor of the U.S. House of Representatives were answered in a third key document, "Suitability of the University of Illinois for a Plant and Animal Sciences Research Center." It was enclosed in a letter to a member of Congressman Richard Durbin's staff. Congressman Durbin, as a member of the House Agricultural Appropriations Committee, was to play a key role in providing federal support of the project, as was Terry Bruce, Illinois Congressman from the 19th district.

In the fall of 1986, legislation approved by the House Agriculture Committee, and subsequently approved by Congress, authorized $30 million to build a Plant and Animal Sciences Research Center at the University of Illinois. This landmark legislation resulted from the dedicated effort of the Illinois congressional delegation, led by congressmen Bruce, Durbin, and Madigan, and the personal endorsements of Kika de la Garza (Texas), chair of the House Agriculture Committee, and Jamie Whitten (Mississippi), chair of the House Agricultural Appropriations Committee.

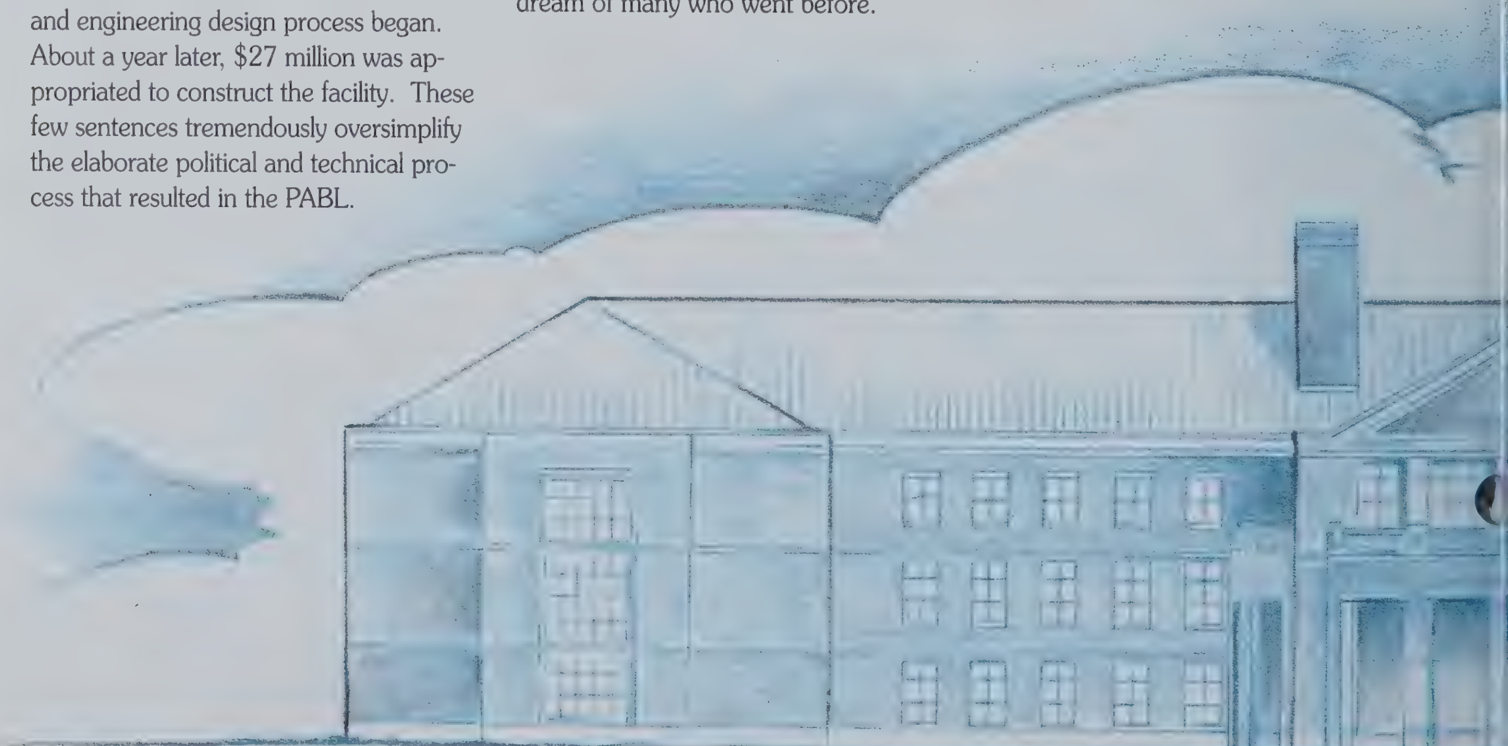
Three million dollars was appropriated to plan PABL in December 1987. The architects were hired and the architectural and engineering design process began. About a year later, $27 million was appropriated to construct the facility. These few sentences tremendously oversimplify the elaborate political and technical process that resulted in the PABL.

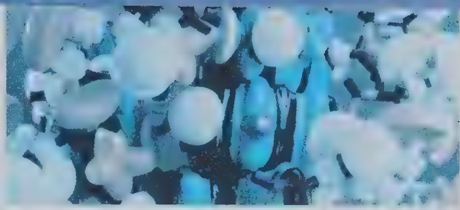
The End of the Beginning

As I write this article, the concrete, bricks, stone, mortar, steel, wood, wire, and pipe are in place, configured as the PABL. People, programs, and equipment are moving in. By the time we dedicate the building in September 1991, it will be full of active, productive, innovative biotechnology research programs.

The people of Illinois and the nation, in an act of collective faith in the people of the University of Illinois, provided the money to plan, construct, and operate the PABL. We know they expect something in return. We know that the PABL and the possibilities it opens are not just our dream, but their dream and the dream of many who went before.

Donald A. Holt, associate dean, College of Agriculture, and Director, Illinois Agricultural Experiment Station





Building a Dream

Douglas B. Bauling

Six years from inception to reality — that's the amount of time it took for the College of Agriculture to realize its dream of the Plant and Animal Biotechnology Laboratory (PABL). This attractive facility, housing more than 100 University and USDA scientists, is a gateway to tomorrow's dynamic agricultural research.

The proposal for a major federally supported facility to support biotechnology in agriculture was formulated in 1985. With support from the Illinois congressional delegation, approval for funding through USDA was successfully pursued. The program statement was developed in 1986 with representatives of the colleges of Agriculture, Veterinary Medicine, and Liberal Arts contributing to the effort. The grant application for planning funds was submitted in July 1986, and planning funds in the amount of $2,853,900 were released that September. The architectural firm of Smith, Hinchman and Grylls Associates, Inc., was selected; and planning began in the spring of 1987. The construction funds grant application was submitted in February 1987, with approval of $26,190,000 in July 1987.

Gilbane Building Company was selected as the construction manager in mid-1988, and bids were received in the fall. Construction began late in 1988 with a November 1990 completion target.

The new facility, designed to support research efforts in designated areas of biological study, is a laboratory with 162,000 square feet of space on four floors. It contains approximately 91,000 net assignable square feet of laboratory-intensive space, with 65 percent oriented toward the support of the plant sciences and 33 percent in support of the animal sciences. The latter includes a research animal facility that will consolidate the on-campus animal research in the College of Agriculture. The remaining space accommodates a conference center that will serve the occupants as well as other College of Agriculture programs.

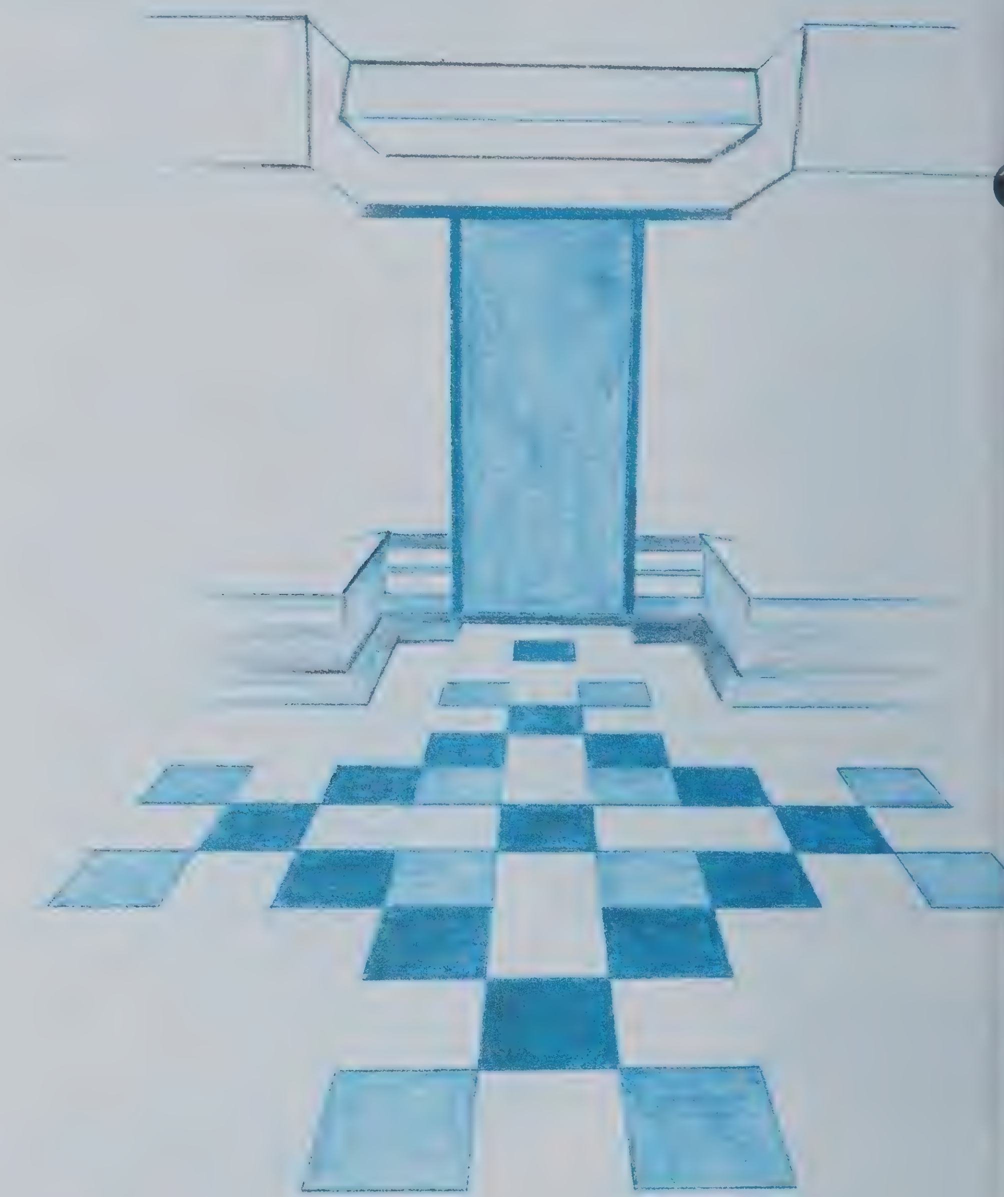
The biotechnology emphasis of the facility's research is concentrated in a few specific areas — tissue-culture research and gene expression/gene identification

programs. The Biotechnology Center in the School of Life Sciences will operate a cell science laboratory in the facility. The photosynthesis research program, a cooperative program with USDA, will relocate from Davenport and Turner halls to join plant biologists and microbiologists from Life Sciences. They'll form the photosynthesis research unit that will occupy about 20 percent of the facility.

The occupants from the College of Agriculture will include major contingents from the departments of Animal Sciences, Agronomy, and Horticulture, with programs from Plant Pathology, Forestry, and Agricultural Entomology. These programs will occupy assigned space as well as share common space dedicated to specific support functions. Included in the latter are growth-chamber rooms, cold rooms, tissue-culture support facilities, autoclave, dishwasher and dryer areas, and darkroom facilities.

Facilities for specific pathogen-free animal research are separated from the general-use areas. A portion of the large animal research area is specifically designed for a higher level of containment than has previously been available to the colleges of Agriculture and Veterinary Medicine. The facility provides the capability to perform surgical procedures on large farm animals and to hold them in cubicles where they can be isolated from the surrounding environment.

To enhance the utilization of the building, it is directly connected to the lower level of the Animal Sciences Laboratory and connected by tunnel to the basement of Turner Hall. Provisions are in place for a tunnel to Bevier Hall, with plans for construction in another year. These connections will provide convenient access for the many scientists planning research studies in the new building.



Douglas B. Bauling, assistant to the director, Agricultural Experiment Station, and planning engineer

Animal Research Facilities

William L. Heckt

The University of Illinois is a leading research institution and maintains a USDA license to conduct animal research. In the College of Agriculture, research facilities house laboratory animals and production farm animals used in studies supporting research, teaching, and extension programs.

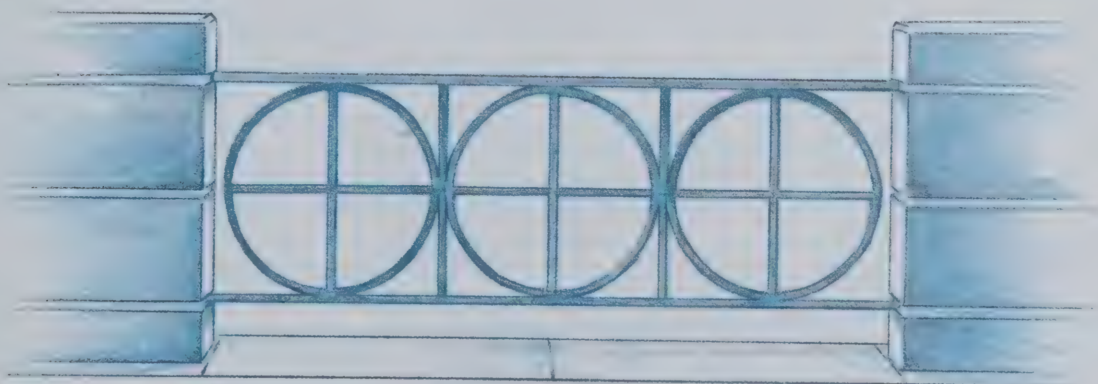
Federal specifications for animal facilities cover design and materials, and include recommendations for ventilation rates, temperature, humidity, lighting levels, and noise control. They ensure that facilities are designed to optimize observation of the animals and sanitation in the facilities, and provide comfortable, environmentally controlled living space for animals.

More importantly, the level of quality control needed for experiments is quite often higher than that required by regulations. Researchers plan, monitor, and assess how a variety of possible variables (environmental, social, health, and experimental) affect the animals. Control of these variables is important for optimal research results. For example, animals that carry genes experimentally transferred from a different breed or species may require specialized care. Some could be sensitive to "normal" environmental conditions and may have decreased resistance to conventional pathogens, as well as normal organisms.

Newly constructed animal research facilities in the College of Agriculture were designed with these factors in mind and provide a controlled physical environment suitable for a wide range of animal species and research needs. The 30,000-square-foot animal research area is located on two floor levels that separate the agricultural farm animal area from the small laboratory animal research activities.

The farm animal area contains poultry rooms designed for housing chicks and laying hens; a room for intensive work with large animals; and a large animal aseptic surgery unit containing eight stalls for cattle, pigs, sheep, or goats. The surgery is equipped with a hydraulic table, built-in piping for anesthetic gases, and a procedures area containing equipment for handling and culturing cells and embryos.

One unique feature of the animal facility is the extensive use of the "Illinois Cubicle" for livestock housing. Seven animal rooms are divided into a series of 36 smaller, individually controlled spaces for isolating single animals or small groups of animals from one another in nearly



equivalent environments. This area was designed to contain genetically altered organisms. Equipped with an electronic security system to control and monitor entry into the facility, the area contains locker rooms with separate showers for entering and leaving the research area. Laboratory rooms with bench space, fume hoods, and biosafety cabinets are located on both the entry and exit corridors. A large steam sterilizer, waste incinerator, small animal equipment washer, and walk-in cold rooms are fixed equipment within this space.

The small animal research area has 19 animal rooms designed for housing mice, rats, guinea pigs, rabbits, and other experimental animal species. Three of the rooms are divided into a total of 15 individually ventilated and temperature controlled cubicles for projects involving small numbers of animals. The area contains a research diet preparation room with scales, mixers, and cold storage; a small animal aseptic surgery; and six rooms with lab benches and equipment to conduct laboratory procedures within the facility.

The entire animal research area is ventilated with air that passes through high-efficiency filters, making it free of dust and smoke. The air can be humidified or dehumidified for animal comfort and research need. The air is not recirculated, so potential contaminants generated in one room cannot enter another through the ventilation system. The ventilation in each animal room can be turned off when the room is not in use, or when it is being cleaned and fumigated. The air temperature and the light cycle can be individually programmed for each animal room.

These features provide the flexibility to accommodate a large variety of research needs. They combine with a good architectural plan and physically strong construction, based on the need for heavy use and a high level of sanitation, to provide an outstanding facility for agricultural and biomedical research.

William L. Heckt, assistant to the director, Agricultural Experiment Station

RFLPs and Corn Improvement

John W. Dudley

Restriction fragment length polymorphisms (RFLPs) are described in a sidebar by Rocheford. For improving corn, RFLPs can be considered "mile-markers" of specific sites on plant chromosomes. Different plants may have different forms of any one marker. By crossing two corn inbreds or genetically uniform lines used as parents of hybrids that each have a different form of the marker, segregation of the marker can be seen in the subsequent generations. For such traits as grain yield, corn-borer resistance, or kernel quality (percent of oil or protein), it has not been possible to identify individual genes or to determine the number of genes responsible for differences in these traits between inbreds.

If two inbreds have different forms of a marker and one of the traits (for example, corn-borer resistance) also differs, it can be determined whether a gene controlling corn borer resistance is located near the marker when the trait is measured on each subsequent plant or its progeny. By using four to ten markers on each chromosome, the number of genes controlling the trait can be determined. Until the development of RFLPs, each trait was known to be controlled by several genes. The effects of each gene were so small relative to environmental effects, however, that individual genes could not be identified and manipulated by plant breeders.

Work in our laboratory and several others has demonstrated the utility of RFLPs to identify genes with significant effects on grain yield and its components. Our challenge has been to develop effective ways to incorporate this technology into corn breeding programs. Several possible ways of using this technology are currently being evaluated. When adding single genes, such as Ht1, a gene for resistance to northern corn leaf blight, into a commercially usable line, RFLPs can reduce the time required to regain the genotype of the line being improved from six generations to two or three. For traits such as corn-borer resistance for which single genes previously have not been identified, identification of two or three markers associated with genes for resistance should allow use of simple procedures for adding corn-borer resistance to commercially used inbreds. We are currently devising procedures for using RFLPs to improve yield.

RFLP technology will not replace proven corn breeding procedures. It is a tool, however, that will enhance the efforts of corn breeders and speed the development of higher quality, higher yielding, more stable corn hybrids.

John W. Dudley, professor of plant genetics, Department of Agronomy

Restriction Fragment Length Polymorphisms

Torbert R. Rocheford

Corn breeders have traditionally developed improved varieties by selecting plants with desirable phenotypes (visual appearance). A plant's phenotype, however, is determined not only by its genotype (genetic composition) but also by the environment in which it is grown.

Because effects of the environment may mask effects of the plant's genotype, the phenotype may provide an inaccurate measure of a plant's actual genetic composition or potential. Consequently, to identify genetically superior plants, very elaborate, expensive plant-breeding techniques are used. By providing direct information about the genetic material of plants, restriction fragment length polymorphism (RFLP) technology may help overcome some of the problems associated with traditional methods of identifying genetically superior plants.

DNA consists of nucleotide bases that comprise genes (coding regions) and the regions between genes (noncoding regions). Variation in the DNA sequence composition of individual plants can be detected by restriction endonucleases. These enzymes recognize specific short (four- or six-) nucleotide base sequences of DNA and cleave the DNA strands at these points. Using electrophoresis, an electrical current is produced across the length of an agarose gel. Because DNA is negatively charged, DNA fragments migrate to the positively charged end at a rate proportional to their relative size.

The fractionated DNA is transferred to nylon membranes by a process called Southern blotting. Previously cloned pieces of DNA from regions of the plant genome under study are labeled with radioactive or nonradioactive labeling methods. The labeled pieces of DNA are hybridized or annealed to the fractionated DNA on the membrane. The membrane is then exposed to X-ray film to detect the regions where the cloned DNA hybridized to the fractionated DNA. The patterns on the film will reveal restriction enzyme-generated hybridization fragments of different lengths (polymorphisms), thus the basis for the term "Restriction Fragment Length Polymorphisms" (RFLPs). Also known as molecular markers, RFLPs mark different chromosomal regions.

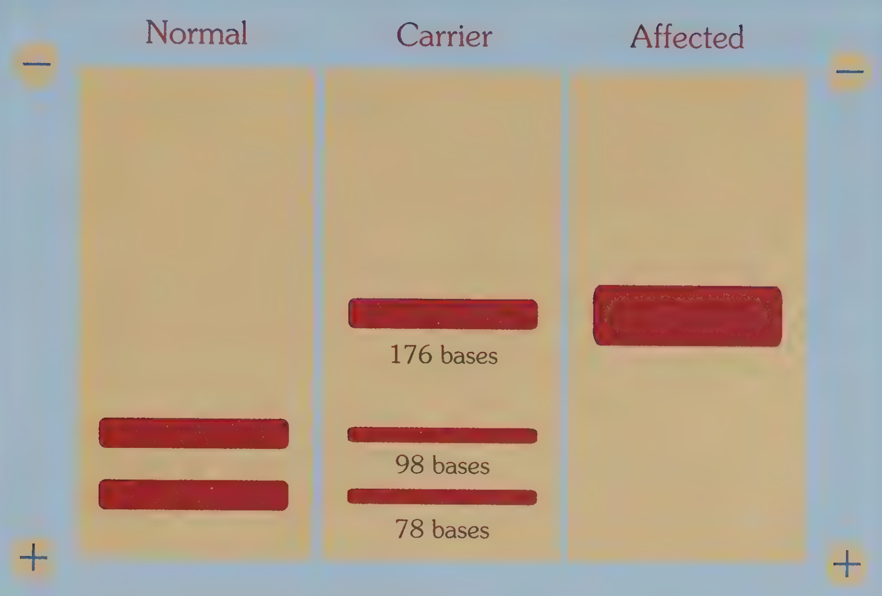
Through evaluation of genetic progenies segregating for RFLP markers and agronomic traits of interest, RFLP markers can be associated or linked with genes controlling important traits. For plant breeding, DNA can be isolated from experimental plants and their RFLP patterns determined with the DNA clones that are linked to important traits. Plants with the desirable RFLP pattern are identified and selected for further breeding, regardless of the environment in which the plants were grown.

Torbert R. Rocheford, assistant professor of corn breeding, Department of Agronomy

In the DNA sequence analysis here, each band represents a different allele of the same gene encoding maise seed protein.

Diagnosing Carriers of Genetic Diseases

James L. Robinson



Electrophoretic patterns diagnostic for normal, carrier, and affected genotypes for bovine citrullinemia. Here, the genes and gene fragments separate in an electric field. Normal animals have two short segments that result from cutting the amplified DNA segment. Affected animals (homozygous recessives) have one long uncut segment because the mutation prevents the cut. Carrier animals (heterozygotes) have three segments (one normal sequence and one mutated sequence).

Genetic diseases or inherited disorders occur in all animal species. Intense selection for improved animal performance, however, may inadvertently increase the frequency of undesirable traits. Because most genetic diseases in domesticated species are inherited as autosomal recessive traits, and carriers generally give no outward indications, the undesirable trait can be spread widely and covertly.

When carriers of any specific condition become prevalent, matings between carriers occur at a high frequency, resulting in affected offspring (homozygous recessives) that will often die prematurely. Identifying and progressively eliminating carriers from a species or breed constitutes an incremental method for improving animals useful to humans.

Biotechnology offers the promise of rapid, economical detection of carriers of genetic diseases. Similar methods are being developed to diagnose genotypes, such as normal, carrier, or affected, for conditions inherited by humans. It is crucial to identify the nucleotide change in the DNA (genetic material) structure responsible for the condition. The changed nucleotide sequence can often be distinguished by using one of hundreds of restriction enzymes that cut the DNA at specific points. The polymerase chain reaction (PCR) can be used to amplify the sequence that contains the mutation before treatment with the appropriate restriction enzyme.

These methods already permit diagnosis of the genotypes for bovine citrullinemia, a genetic disease of Holstein-Friesian cattle. In Australia, one of every 250 calves born is affected (homozygous recessive) and dies of neurological dysfunction within five days of birth. Among U.S. Holstein cattle, carriers exist; but their frequency, expected to be low, is presently unknown.

The diagnostic protocol consists of
- obtaining a blood, semen, or tissue sample of DNA from the test animal;
- extracting the DNA from the sample;
- amplifying (using PCR) a nucleotide sequence that contains the site of the mutation;
- treating the amplified sequence with a restriction enzyme that cuts only the normal sequence; and
- electrophoresing the resultant DNA to reveal the number and size of DNA segments present.

Electrophoresis is the movement of molecules through a fluid or gel under the action of an electrical current. The figure shows the electrophoretic patterns diagnostic for the normal, carrier, and affected genotypes of bovine citrullinemia.

James L. Robinson, professor of biochemistry, Department of Animal Sciences

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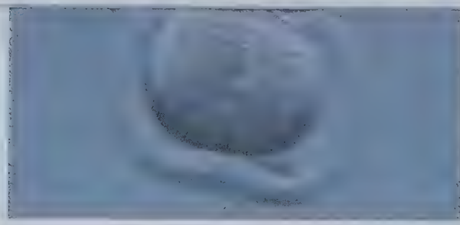

Animal and Plant Transformation: The Application of Transgenic Organisms in Agriculture

Matthew B. Wheeler, Stephen K. Farrand, and Jack M. Widholm

A transgenic organism carries in all its cells a foreign gene that was inserted by laboratory techniques. Each transgenic organism is produced by introducing cloned genes, composed of deoxyribonucleic acid (DNA) from microbes, animals, or plants, into plant and animal cells. Transgenic technology affords methods that allow the transfer of genes between different species.

Animal Transformation

Through transgenic animal transformation, new genetic information is introduced into an animal in *one* generation without compromising or limiting the overall pool of genetic information. Transgenic animals are produced by inserting genes into embryos prior to birth. Each transferred gene is assimilated by the genetic material or chromosomes of the embryo and subsequently can be expressed in all tissues of the resulting animal. The objective is to produce animals which possess the transferred gene in their germ cells (sperm or ova). Such animals are able to act as "founder" stock to produce many offspring that carry a desirable gene or genes.

Transgenic animals have been produced by three methods: microinjection of cloned gene(s) into the pronucleus of a fertilized ovum, injection of embryonic stem cells into embryos, and exposure to retroviruses. The third method is not discussed in this article.

The first method is the one that is most widely and successfully used for producing transgenic mice. After mi-

To produce transgenic mice, Matthew B. Wheeler microinjects DNA into the pronucleus of one-cell embryos.

croinjection, the recently fertilized single cell embryos are removed from the animal. Micromanipulators on a specially equipped microscope are used to grasp each embryo. A glass pipette drawn or pulled to a fine point immobilizes the embryo on one side, as shown in the photos to the right. On the opposite side, the foreign DNA is injected into the embryo's pronucleus — either of two nuclei (male or female) containing half the chromosomes of a fertilized ovum — with a second finely drawn injection needle. After the injection, the embryos are transferred back into the hormonally prepared or pseudopregnant recipient females or foster mothers. The recipients follow normal pregnancy and deliver full-term young. This method is presently the most efficient for generating transgenic animal lines: about 1 to 4 percent of the injected embryos result in a transgenic offspring.

Injection of cloned DNA into embryos. One-cell embryo is positioned for micro-injection into the pronucleus (left). The plasma membrane has been pierced, and the tip of the needle remains inside the pronucleus, while DNA is expelled from the needle, causing the pronucleus to swell visibly.

The second method involves microinjection of embryonic stem (ES) cells derived from the inner cell mass of blastocyst-stage embryos (about 7 days postfertilization) into embryos to produce "hybrid" embryos of two or more distinct cell types. The ES cells are able to produce all tissues of an individual. Once isolated, ES cells may be grown in the lab for many generations to produce an unlimited number of identical cells capable of developing into fully formed adults. These cells may then be altered genetically before being used to produce embryos. When these transformed cells participate in the formation of sperm and eggs, the offspring that are produced will be transgenic. Results have shown this method to be promising for producing transgenic mice. Studies are presently under way at the University of Illinois Department of Animal Sciences to develop ES cell lines for livestock species such as swine, cattle, and sheep.

These methods, which enable the insertion of foreign genes into embryos, have provided the tools for producing new strains or breeds of animals that carry new, beneficial genetic information. These technologies do not produce new species but work within the established genetic framework of existing species to improve them. Some new strains developed include leaner, more feed-efficient, faster-growing swine containing additional copies of the growth hormone gene, and mice containing the regulatory elements of the human immunodeficiency virus (HIV) genome. The latter are used as a noninfectious animal model for the study of AIDS.

The scope of the information acquired from transgenic animal technology is pertinent to virtually all areas of modern agriculture and biomedical science — cancer research; immunology; developmental biology; gene expression and regulation; and models for human genetic diseases such as muscular dystrophy,

Lou Gehring's disease, and sickle cell anemia. Potential applications for transgenic animals include manipulation of milk composition, growth, disease resistance, reproductive performance, and production of pharmaceutical proteins by livestock.

Plant Transformation

There has been much excitement in the last few years about our ability to genetically engineer plants using the new techniques of gene isolation and insertion. Paired with standard methodologies of plant tissue culture and plant regeneration, these new techniques allow us to construct transgenic plants that contain and express a single, well-defined gene from any source — microbe, animal, or other plant species. The transgenic plants, usually normal in appearance and character, differ from the parent only with respect to the function and influence of the inserted gene.

This directed genetic engineering of plants requires that genes of interest are available, that the gene be introduced into plant cells capable of regenerating into intact plants, and that the gene carries with it a selectable marker so that the transformed plant cells can be isolated from a large population of untransformed, normal cells. Finally, the transformed plant cell must retain its capacity to regenerate. Certain species such as tobacco and petunia regenerate plants quite easily, making transgenic plants readily obtainable. Although corn, soybean, and wheat — the primary agricultural crops of Illinois and the Midwest — are more recalcitrant to these manipulations, progress is being made toward routine transformation and regeneration of transgenic progeny of these species.

Several techniques can introduce genes into plant cells. Perhaps the most successful method involves the pathogenic bacterium *Agrobacterium tumefaciens*, which has the innate ability to transfer DNA to plant cells. In nature, this transfer results in formation of plant tumors (crown galls) at the infection site. Molecular biologists, however, have disarmed this bacterium and constructed domesticated strains that no longer cause tumors but transfer any DNA of interest to plant cells. The major disadvantage of the highly efficient *Agrobacterium* system is that it does not work with all plant species, most notably the cereals.

Other techniques use physical or chemical agents to transfer DNA into plant cells. Protoplasts, plant cells that have been stripped of their protective cell walls, will take up pure DNA when treated with certain membrane-active agents or with electroporation, a rapid pulse of high-voltage direct current. Once inside the cell, the DNA is integrated and the foreign gene will express. These two techniques largely depend upon the development of protoplast systems that retain the capacity to regenerate intact plants. Transgenic corn, rice, and soybean have been produced with these techniques, especially electroporation. Success rates, however, are low, and the techniques not very reproducible.

DNA can also be microinjected into target plant cells using very thin glass needles in a method similar to that used with animals. Microinjection, however, has produced only a few transgenic plants. The technique is laborious, technically difficult, and limited to the number of cells actually injected.

Biolistics, a new method, involves accelerating very small particles of tungsten or gold coated with DNA into cells using an electrostatic pulse, air pressure, or gunpowder percussion. As the particles pass through the cell, the DNA dissolves and becomes free to integrate into the plant-cell genome. This improbable technique actually works quite well and has become, along with electroporation, one of the methodologies of choice. Biolistics has the advantage of being applicable to whole cells in suspension or to intact or sliced plant tissues. For example, plant meristems or tissues capable of regeneration can be targeted directly. Unlike transformation or electroporation, the technique does not require protoplasts or even single-cell isolations. Using biolistics, transgenic corn and soybean plants have been produced that contain heritable copies of the inserted gene.

Only a few genes of agronomic importance have been inserted into plants: genes conferring resistance to certain insects and viruses and also those conferring tolerance to broad-spectrum herbicides. The latter result in increased herbicide specificity, allowing the farmer to use more effective, environmentally safe chemical agents. More recently, a gene has been introduced into tomato that delays overripening and prolongs shelf life of the fruit.

Other traits of interest include those associated with grain quality. Genes to increase the content of amino acids such as lysine, methionine, and tryptophan in seed will increase nutritional value, thereby decreasing the need for amending grains with costly feed supplements.

All traits discussed here are associated with expression of single genes. But many important agronomic traits such as yield and lodging are not well understood and are controlled by many genes. Manipulating such polygenic traits by genetic engineering will require further research and the development of techniques for isolating, reconstructing, and transferring complex blocks of genes. Extensive and promising research is being conducted about additive disease resistance and stress tolerance, important polygenic traits. Plant genetic engineering is thus moving slowly but steadily from the laboratory bench into the field.

Matthew B. Wheeler, assistant professor of animal sciences; Stephen K. Farrand, professor of plant pathology and microbiology; and Jack M. Widholm, professor of plant physiology, Department of Agronomy

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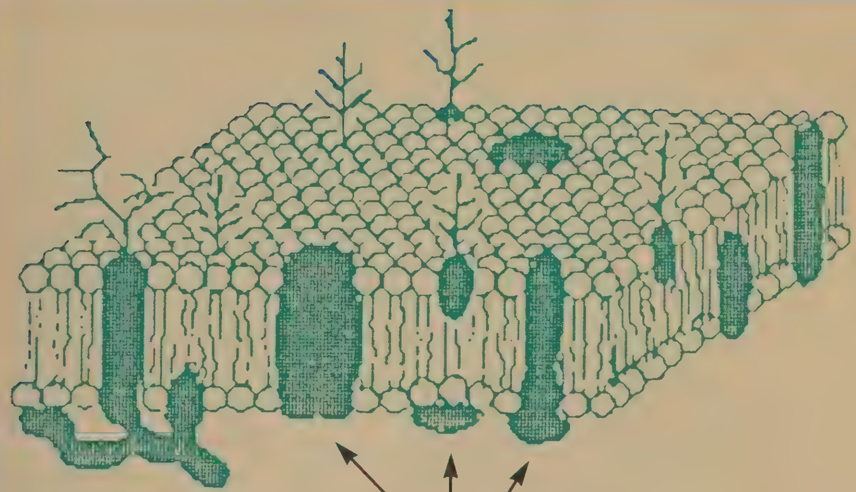


Diagram of the structure of biological membranes, showing the lipid bilayer and membrane-associated proteins.

Source: Adapted from *Biochemistry and Function of Vacuolar Adenosine-Triphosphatase in Fungi and Plants*, B.P. Marin, ed. (1985).

Biotechnology and Plant Membranes: Future Implications

Donald P. Briskin

Membranes define the outer boundary of plant cells and the structure of their internal organelles. In this role, membranes regulate the flow of materials between cells and their environment as well as their internal compartments. These materials can include mineral nutrients acquired from the soil and metabolites important for crop growth and development. At the whole-plant level, transport across membranes can serve to define allocation patterns for the products of photosynthesis and metabolism, which can determine the quantity and quality of crop yield.

Membranes are composed primarily of lipids and proteins. The bilayer lipid arrangement defines the plane of the membrane to which proteins are associated (see figure). The lipid portion of the membrane can represent a substantial barrier to material flow, but the proteins associated with the membrane impart the means for selective transport and accumulation of solutes. This function is defined by the structure of the transport protein, which is, in turn, a reflection of its primary amino acid sequence encoded by its respective gene.

With current advances in molecular biology, this approach would appear to represent a powerful tool for modification of membrane transport processes, with the ultimate goal being the development of improved crop cultivars. But there is a paucity of basic knowledge about how membrane transport systems operate and are regulated. Therefore, before biotechnology of membrane processes can become a reality, much work is needed to define the function and structure of membrane transport proteins at the molecular level.

At the University of Illinois Agricultural Experiment Station, work is being conducted to understand the biochemistry of the transport system involved in nitrate uptake by maize roots. This mineral nutrient represents a major limiting factor for determining maize growth and yield as demonstrated by the increase in yield for maize grown in Illinois with the advent of nitrogen fertilizer application. Our work focuses on not only understanding which properties of this transport system determine its function and regulation but also on elucidating the factors that limit its efficiency. The ultimate goal is to provide important information about this transport system, so that its activity can be modified through gene manipulation to produce crop plants with greater efficiency for nitrate acquisition and allocation. Potentially, then, novel maize cultivars could be developed that require less nitrogen fertilizer for a given yield and hence realize higher productivity.

Donald P. Briskin, associate professor of plant physiology, Department of Agronomy

Genetic Transformation of Crop Species

Angus G. Hepburn

Because corn and soybeans are the two major feed crops in Illinois, there is great interest in genetically transforming these species for such traits as increased protein quality, seed yield, or altered lipid content. Unfortunately, the techniques that work well with tobacco or petunia, so-called "model" species, do not work as well with corn and soybeans. Researchers are trying to determine the cause of this reduced efficiency. The problems arise mainly from difficulties in delivering DNA containing the desired gene to plant cells that are capable of regenerating into whole plants. In the model plant species, disruptions (separations into small clumps of cells, single cells, or protoplasts) are an integral part of the successful transformation process, but when comparable disruptions are applied to tissues from the crop species, the fragmented tissues are incapable of regenerating whole plants. Thus, any DNA delivery technique that requires such disruptions to the crop species will be of little value.

Our research uses two related, complementary approaches to overcome these problems. One approach is to develop delivery of DNA to organized cell clumps or tissues that retain the ability to regenerate whole plants. The major barrier here is the rigid cell wall that surrounds the plant cell. Purified DNA must pass through this barrier to reach the cell membrane and enter the cytoplasm and, eventually, the nucleus where DNA can be integrated into the plant cell genome.

Recent developments in electroporation (using a pulsed electrical field) or the new microprojectile technology are encouraging. Under the right conditions, it appears that the forces involved can move the DNA through the cell wall without significant damage to the genetic material. Attempts to get *Agrobacterium tumefaciens*, the biological vector system, to deliver DNA to regenerable cells also show success, at least for soybeans.

Assistant biologist David R. Duncan selects a culture for examination.

The second approach uses techniques to disrupt the tissues of the crop species so that the highly efficient protocols used for transformation of the model species are also effective, while allowing the disrupted cells to retain the capability of regeneration. Again, recent advances in tissue-culture technology are proving invaluable for soybean transformation, and progress is being made in developing comparable systems for corn.

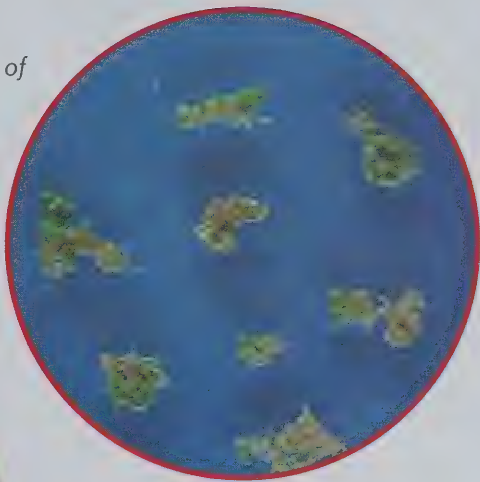
Still another problem has been found in detecting transformed cells or tissues in the mixture of transformed and untransformed cells produced in a typical transformation experiment. Usually an antibiotic-resistance selection marker (for example, kanamycin resistance) is included in the vector molecule with the desired gene for plant improvement. Such an approach gives a highly efficient selection system for the model species. Unfortunately, the sensitivity of crop species to the most common antibiotic-resistance selection markers is low or variable so that only a low-level enrichment is obtained. When transformation efficiency is one in 1000 or lower, even a 100-fold enrichment for transformed cells or plants requires a considerable investment in plant screening and analysis. Much effort has therefore gone into developing better selection markers for use with crop species.

The antibiotic Hygromycin B seems to be the best selection candidate for soybeans and the herbicide Basta, the best for corn. Resistance genes for both have been found in bacteria and modified to work in plants. The chemicals appear to discriminate well between transformed and untransformed cells when the two are mixed and used for selection. Although neither is as clean in its corresponding crop as is kanamycin in the model species, the enrichment is enough to make the screening for transformed cells time and cost effective. Because of subtle differences in the ways different

plant species control gene expression, the selection markers are being tailored to specific crops to ensure that they are expressed at the highest possible level. This practice has been found to compensate for reduced levels of expression resulting from species specificity of expression-controlling elements.

With these improvements, the future looks promising for successful transformation of the major crop species.

Angus G. Hepburn, associate professor of plant molecular genetics, Department of Agronomy



Improving Photosynthesis by Gene Engineering

William L. Ogren

In photosynthesis, a plant uses sunlight to remove carbon dioxide from the atmosphere and converts it into sugar and starch. The plant uses these for growth of seeds, fruits, tubers, or other plant parts of economic value, such as leaves, roots, and stems. Because crop productivity increases when photosynthesis occurs more rapidly, much research is directed toward improving this process.

One approach being taken by a USDA research team at the University of Illinois Department of Agronomy is to speed up the first step of photosynthesis. Five years ago, this team discovered an enzyme that governs the rate at which leaves absorb carbon dioxide. The gene that determines the structure of this enzyme, and thus the enzyme's activity, was then obtained. Using genetic engineering, several different changes were made in the gene to alter the properties of its enzyme product.

It cannot be predicted how changes in enzymes will affect their activity. Because enzymes have highly organized structures, changes usually result in less activity. In this case, however, one of the altered enzymes had more activity than normal. Attempts are now being made to incorporate the modified genes into plants, using standard methods of genetic transformation. Following transformation, photosynthesis measurements of the transgenic plants will be made. Such tests will determine the possibility of improved plant productivity by modifying this component of photosynthesis.

William L. Ogren, research leader, USDA/ARS, and professor of agronomy

A comparison of woody transplants rooted in vitro (left) or removed from culture and rooted ex vitro in soil (right). A video image analysis system records the superior root structure produced ex vitro.

Bridging Plant Biotechnology and Field Research

Mary Ann L. Smith

New biotechnological strategies to manipulate plant germplasm in vitro have advanced at a staggering rate. Despite the intensive research interest in plant biotechnology, scientific progress and commercial exploitation frequently have been blocked at the crucial "transition" stage — from novel plant regenerates exhibiting superior growth or stress tolerance in the laboratory to field-proven crop plants.

Biotechnology in Horticulture

Robert M. Skirvin

Horticultural scientists study crops that are used for food, drugs, or aesthetics. Many of these crops are unique or so highly specialized that they are no longer propagated sexually by seeds but rather asexually by such methods as cuttings, grafting, layering, and tissue culture. Seedless grapes, potatoes, maple trees, and roses are some examples of crops that are propagated by some or all of these methods. Although some cultivars are very well known and widely grown, problems related to disease susceptibility, fruit or flower quality, or growth habits arise occasionally.

Traditional sexual-breeding programs can improve some of these crops. The process can be slow, however, especially in tree-breeding programs.

Many of our most popular flower, fruit, and vegetable cultivars are very old. The public often rejects a new cultivar in favor of a better-known cultivar that has endured. The asexually propagated 'Bartlett' pear, for example, introduced in 1770, remains the world's standard for pear quality. Because most new cultivars fail this test, they remain as local cultivars or are discarded.

Another method to improve cultivars is to screen "sports" or mutations that occur naturally, but rarely, on cultivars grown in a field, greenhouse, or laboratory. For example, the green-fruited 'Bartlett' pear sported to yield the red-fruited 'Red Bartlett'. Although this natural variability is useful for plant improvement, the process is random and many plants must be inspected to find a desirable mutant type.

Variability is a universal feature of plant tissue-culture, a method whereby plant parts are grown aseptically on artificial medium. Variation that develops under tissue-culture conditions is now called somaclonal variation. In tissue culture, whole plants can develop from single cells under the proper stimuli of growth regulators, growing medium, and light. Although the precise cause of somaclonal variation remains unknown, its induction and use have become important research topics.

The exploitation of natural and induced variation seems especially applicable for improving older asexually propagated cultivars like 'Bartlett' pear. During the past 200 years, the clone has been exposed to natural radiation — ultraviolet and cosmic rays — and various sprays and pollutants. These exposures have probably resulted in mutations that stabilized as islands or regions within the body of these plants. When a cultivar possesses mutant cells (natural or artificially induced), whole plants derived from these cells may express the mutation and be classified as somaclones.

The common obstacles to this transition are twofold: 1) characteristics evident in cell culture may not be expressed at the whole-plant level under natural production conditions, and 2) rooting and acclimatization of in vitro plants to field or greenhouse conditions may result in serious losses in plant survival rates and quality. Research efficiently linking laboratory biotechnology and traditional field-performance research is needed to foster rapid, practical realization of the gains offered through biotechnology. To enhance this transition, we have developed whole plant microculture (WPMC) intermediate testing systems and video-image analysis systems.

A WPMC system can provide a small-scale, efficient, highly controlled test environment for regenerates from cell culture, to verify that traits selected at the cell level are still expressed in the whole plant. For example, definitive and reproducible detection of superior salt tolerance traits for turfgrasses, tomatoes, and greenhouse floriculture crops have been achieved in rigorously controlled WPMC systems. With the aid of a computer, a video camera processes images of test microplants and allows subtle detection of plant responses to salt stress in the root and shoot zones. The image analysis system automates collection of data about plant growth, development, and disease symptoms. Traits evaluated in WPMC have correlated well with traits measured in vivo in field or growth chamber tests.

The transition from biotechnology research to production can also be obstructed at the stages of rooting and acclimatization, so that regenerates from culture can be evaluated in vivo. In some cases, the regenerated plants that survive transition have abnormal growth and poor tolerance to environmental stress.

Quantitative and qualitative differences in root character after in vitro and ex vitro rhizogenesis, or rooting initiation, dictates plant survival and has long-term repercussions for mature woody specimens that we originally produced in vitro. The nondestructive advantage of using images to evaluate plant quality has allowed us to identify specific factors that affect regenerated clones' chances for survival. This information provides new clues on how to manipulate in vitro strategies to ensure ultimate production of superior plant selections for either field or landscape conditions.

Research systems combining WPMC and image analysis, as described here, provide an excellent means to efficiently evaluate and use novel genetic material in terms of whole-plant attributes.

Mary Ann L. Smith, associate professor of plant physiology

■

Researchers in the Department of Horticulture have used somaclonal variation to obtain thornless blackberries and red pear trees. 'Lincoln Logan', one of our thornless blackberries derived from tissue culture already has been released as a cultivar. Another thornless blackberry is at an advanced stage of testing. We also hope to find variations in fruit color in our small orchard of apple trees that were derived from tissue culture.

Because there may be an upper limit to natural variation within a cultivar, biotechnology protocols are important to supplement and direct the type of variation that we encounter. Researchers at the Department of Horticulture have worked with tomato plants that possess a gene from bacteria *(bt)* that gives resistance to certain caterpillars. Other scientists in the department have produced Solanaceous plants with good resistance to certain herbicides and are trying to introduce virus resistance to apple trees.

How much progress can be expected using biotechnology will vary with the clone, the age of the culture — older cell lines often show more somaclonal variation than newer lines — use of mutagenic agents such as radiation or chemical mutagens, and selection pressure applied to single-cell clones for stress conditions such as salt level, herbicides, microorganisms or their by-products, and specific metabolites. For instance, by placing a variable population of cells in a medium with herbicide, the cells that survive should have some resistance to the herbicide. Progress will also depend on the availability of useful genes for transfer to horticultural crops.

Robert M. Skirvin, professor of horticulture

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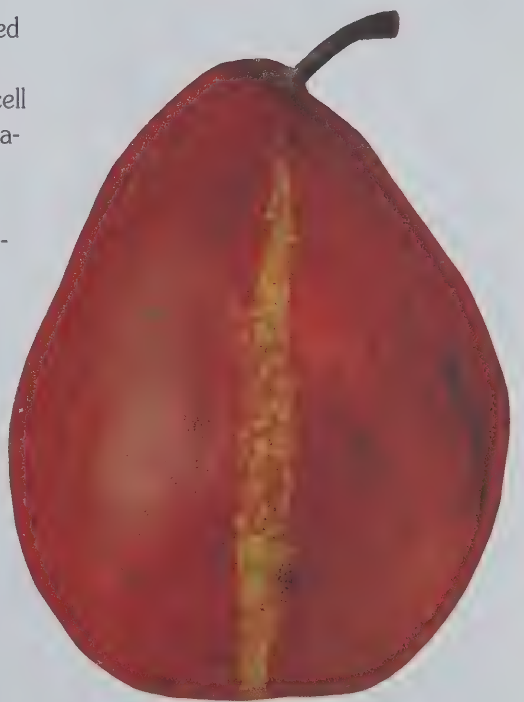


Chimera. This pear fruit has both red and green tissues growing together. Theoretically, red trees can be produced from the red sectors and green from the green sectors.

Biotechnology in Forestry

David E. Harry, Jeffrey O. Dawson, and Robert M. Skirvin

Scientists at the Department of Forestry are conducting biotechnology research to better understand some of the diverse organisms that occupy forests, as well as to enhance methods for genetically manipulating these organisms.

Gene structure and function. Trees must often cope with environmental stress to survive. Anaerobic stress, caused by a lack of oxygen, occurs whenever demand for oxygen exceeds supply. Although a plant may experience anaerobic stress after a flood, it may also occur within metabolically active tissues of a nonflooded plant. Anaerobic stress activates a small set of genes and alters biochemical processes that generate cellular energy.

Among the genes activated by anaerobic stress, those encoding alcohol dehydrogenase (ADH) are understood the best. ADH is the enzyme that catalyzes the interconversion of acetaldehyde and ethanol. This enzyme is essential for plants to survive short-term exposures to flooding, but its physiological function is not clearly understood.

Patterns of ADH expression in woody plants are unusual when compared to nonwoody plants, probably because anaerobic stress commonly occurs within metabolically active tissues of tree stems, such as the cambium. Using classical genetic tools and recombinant DNA methods, we are studying the gene (or genes) responsible for ADH expression in different tissues of pines and cottonwoods to understand the molecular mechanisms responsible for switching these genes on and off. These studies will enable us to better understand how anaerobic stress affects tree growth and wood production.

Tissue culture and plant regeneration. Moving genes from test tubes into actual trees requires three methods: one method to shuttle genes into plant cells, one to aseptically grow plant tissues, and one to regenerate trees from isolated tissues. Our research addresses several of these areas.

One project regenerates plants from selected clones of the eastern cottonwood (*Populus deltoides*) and from immature *Populus* embryos. Because they grow so rapidly, *Populus* species are prime candidates for windbreaks and for producing wood or fiber. Four- to ten-year-old *Populus* trees can be harvested for woody biomass (to be burned directly or converted to chemical fuels) or for pulpwood.

We can dramatically alter plant development in culture by changing the type of sugar or hormones contained in growth media. We can now regenerate plants from isolated tissues of mature individuals as well as from immature embryos. Because hybrid embryos can be rescued before they abort, the latter method allows sexually incompatible *Populus* species to be crossed.

In collaboration with researchers from the Department of Plant Pathology, an-

Alder seedlings sprayed with water containing Frankia *collected from different places. Later, roots will be examined to determine the number of nitrogen-fixing nodules formed by the different* Frankia *isolates. Molecular fingerprinting may provide a means to directly identify the particular* Frankia *isolate present in the module.*

Many kinds of adaptations allow these baldcypress trees to tolerate flooding. Although their stems are above water and bathed in air, rapidly growing tissues beneath the bark may suffer a shortage of oxygen. Alcohol dehydrogenase enzymes may allow such tissues to maintain rapid growth despite shortages of oxygen.

other project transfers genes into trees and shrubs that form root nodules containing *Frankia*, a nitrogen-fixing bacterium with a diverse range of plant hosts. Initial experiments have infected plant tissues from red alder (*Alnus rubra)* and Russian olive (*Elaeagnus angustifolia*) with the bacterium *Agrobacterium rhizogenes*.

By infecting these and other plant species, *Agrobacterium* transfers a few bacterial genes into the cells of the host plants. This natural process provides a mechanism to shuttle selected genes into plants. From infected plants, we have observed morphologically and biochemically distinct shoots and roots we believe to contain transferred genes. These methods will enable genetic manipulation of nitrogen fixation, which may reduce the need for nitrogen fertilizers.

Although plants need nitrogen to grow but cannot use atmospheric nitrogen, nitrogen fixation is a process that converts atmospheric nitrogen to forms that the plants can use. Legumes such as soybeans fix nitrogen using *Rhizobium,* a different bacterium.

Microbial biology of *Frankia.* Despite the economic and environmental importance of nitrogen fixation, we know relatively little about *Frankia*. Recent technological advances allow "fingerprinting" of *Frankia* strains based on the nucleotide sequence of RNA contained in ribosomes or cellular organelles that facilitate protein synthesis. We have found that ribosomal RNA varies considerably among *Frankia* strains, so we can now characterize Frankia collected from different nodules on the same plant, from plants growing in different areas, or even from different soil samples. These methods will help to characterize the population dynamics of these poorly known nitrogen-fixing microorganisms.

David E. Harry, assistant professor of forestry; Jeffrey O. Dawson, professor of forestry; and Robert M. Skirvin, professor of horticulture

Biotechnology of Aging

Keith W. Kelley

It's exciting when scientists can apply what they learn from fundamental research on livestock to important medical problems of humans. One of the hottest developments in biotechnology of both livestock and humans is somatotropin or growth hormone, a new genetically engineered protein. As yet, growth hormone has not received approval from the Food and Drug Administration (FDA) for use in the animal food chain. However, recombinant human somatotropin, which received FDA approval in October 1985, is being used to treat about 15,000 children in the United States who were born with a deficiency of growth hormone. With treatment, these children may grow up to four inches per year. In 1989, worldwide sales of somatotropin exceeded $300 million.

Somatotropin has generated much excitement and concern about other potential clinical uses. Somatotropin may help control obesity in middle-aged humans, reverse some aspects of the aging process, improve wound healing in burn patients, augment the physical abilities of athletes, and both improve growth rate and reduce carcass fat in domestic food or animals.

The *New England Journal of Medicine* reported in 1990 that giving somatotropin to men between 61 and 81 years of age increased lean body mass and reduced body fat. Unfortunately, the long-term effects on human or animal health are not yet known, but somatotropin is known to affect several activities of cells of the immune system.

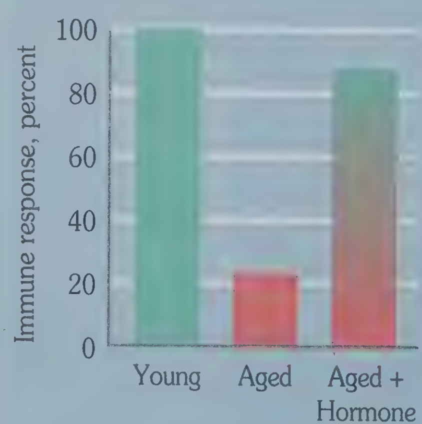
Aging's Effects on the Human Immune System

Rapid growth of the aging population and the enormous accompanying costs of health care make research about aging everyone's concern. In the United States, nearly 30 million people are over age 65, and this number will double within the next 30 years.

By the year 2000, 5 million Americans will be over age 85. Nearly 40 percent of those over 85 require daily assistance from relatives or professional caregivers to maintain normal, daily activities.

As a group, the elderly have an increased incidence of respiratory, neoplastic, arthritic, and cardiovascular diseases, and a higher incidence of mortality from bacterial infections due to gram-negative sepsis. Among the aged, influenza and pneumonia are the fourth leading cause of death; tuberculosis occurs most often and leads to the highest death rate among the elderly. Infectious endocarditis causes over 50 percent of deaths when it occurs in people over age 60. Fifteen percent of the aged population suffer from urinary tract infections. The elderly also have an impaired ability to develop fevers following infection. It is generally believed that the increase in disease prevalence is related to aberrations that occur in regulation of the immune systems of the aged.

Somatotropin-secreting pituitary cells significantly improve the immune response of aged rats.



Source: Kelley et al., 1986, *Proceedings of the National Academy of Science USA*, 83:5663.

Somatotropin, Aging, and the Immune System

Five years ago, immunologists, muscle biologists, and veterinarians working within the College of Agriculture discovered an important link in aged animals between the immune system and somatotropin. For years it has been known that the size of the thymus gland in both humans and animals decreases with age. It is also now recognized that human somatotropin secretion declines as we age. Maximal size of the thymus gland coincides with maximal secretion of somatotropin at puberty; by age 60, only fatty remnants of the thymus gland remain.

This process was thought to be irreversible. We postulated that giving somatotropin in the form of hormone-secreting pituitary cells might permit the thymus gland to grow again in aged animals. We also tested the possibility that this regenerated thymus gland might aug-

ment certain aspects of the immune response that deteriorate during aging.

Results from these experiments were amazing. As expected, we could detect only remnants of the thymus gland in control rats equivalent to 54 year-old humans. But aged rats that had been implanted with hormone-secreting pituitary cells were able to regenerate their thymus glands to the point of being indistinguishable from those of young rats. Furthermore, the immune response which normally declines with age (as assessed by the growth of T lymphocytes) was significantly improved (see figure). T lymphocytes, cells that are derived from the thymus gland, are required for most immune responses.

We have now shown that the real cellular target for the action of somatotropin may be the macrophage, a type of phagocytic cell in the immune system that eats bacteria and kills tumor cells with toxic chemicals. Because secretion of growth hormone declines in older humans and animals, these data suggest that genetically engineered somatotropin may be useful in delaying or preventing the age-related change in various immune functions. Experiments are evaluating these possibilities, but research on aging is quite expensive. For example, scientists pay as much as $150 for a two-year-old rat — rats can live up to three years under excellent management conditions. The enormous costs of conducting aging research, which requires between 50 and 100 rats per study, limit the number of experiments that can be run.

Somatotropin and the Immune System of Livestock

The experiments with aged rats provided the impetus to study whether somatotropin affects the immune system of farm animals. Initial experiments concentrated on pigs' phagocytic cells, such as macrophages and neutrophils, which are critically important for destroying many types of bacterial and fungal pathogens. Using genetically engineered porcine somatotropin that has already been proven to increase growth rate and reduce carcass fat, we showed that this protein increases the capability of macrophages to produce a free radical known as superoxide anion. This molecule plays an important role in the killing of bacteria by porcine phagocytic cells. We have now shown in humans (University of Illinois faculty and graduate students) and in pigs and cattle that recombinant somatotropin increases the secretion of superoxide anion by another type of phagocytic cell, the polymorphonuclear neutrophil. In pigs, these somatotropin-treated neutrophils are also more efficient in killing *Escherichia coli* in vitro.

All the experiments described above were conducted by adding recombinant porcine somatotropin to phagocytic cells in a test tube, so it is not known if similar results will be obtained if this genetically engineered version of somatotropin is administered directly to pigs. New data from scientists at the University of Guelph in Canada, however, show that injecting recombinant bovine somatotropin into lactating dairy cows increases a number of immune responses.

Summary

New techniques in molecular biology can potentially revolutionize animal agriculture. Somatotropin is the first genetically engineered protein that has been extensively tested and shown to increase a number of economically important traits in dairy cattle, pigs, and sheep. Research conducted at the University of Illinois has shown that this same molecule might also be one of the important keys to understanding why we age and how to augment the immune response of both humans and livestock.

Keith W. Kelley, professor of immunophysiology, Department of Animal Sciences

■

In Progress

New Biosynthetic Pathway

The discovery of new metabolic intermediates brings scientists one step closer to figuring out how plants make chlorophyll b, a pigment important for photosynthesis and plant production.

University of Illinois plant physiologist Constantin Rebeiz, postdoctoral fellow Vinay Shedbalkar, and graduate student Ioannis Ioannides have discovered new tetrapyrroles which appear to be intermediates in chlorophyll b formation.

"This is like finding a key that will allow the whole process to unfold. Now, we can investigate the biochemistry of the various reactions responsible for chlorophyll b formation in nature," Rebeiz said. "The implications are fundamental at this stage; it is a discovery that others will build upon."

Scientists identified chlorophyll b in the 1940s. Although they have developed hypotheses to explain how plants produce the pigment, the process remains a mystery. About eight years ago, Rebeiz, Shedbalkar, and Ioannides became intrigued enough to begin working on the problem at the U of I Laboratory of Plant Pigment Biochemistry and Photobiology.

Rebeiz said the chlorophyll b biosynthetic pathway appears to be highly complex and may take several years to research. Papers on the progress of this ongoing research are being prepared for journal publication.

■

Researcher Honored for Contribution to Agriculture

Research aimed at boosting the capacity of a crop plant to make its own food for growth and development earned University of Illinois plant physiologist William Ogren the 1990 Alexander von Humboldt Foundation Award. Each year, a U.S. scientist who has made the most significant contribution to agriculture in America over the past five years is selected for the award, which carries a $10,000 stipend.

The award recognized the recent progress Ogren's research team has made in the laboratory. With a goal of changing plant genes to make photosynthesis more efficient, they have identified key enzymes, genes, and proteins and developed techniques for isolating, cloning, and modifying these genes. Future work will focus on transferring altered genes.

Ogren holds joint appointments in the U of I Agronomy and Plant Biology departments and is research leader of the U.S. Department of Agriculture's Agricultural Research Service Photosynthesis Research Unit.

■

Destruction of Cancer Cells

For innovative research, two disciplines may be better than one. Building upon their own independent research in cell metabolism, University of Illinois plant physiologist Constantin A. Rebeiz, animal scientist Keith Kelley, and animal sciences graduate student Natalie Rebeiz, have combined skills to develop a treatment that causes cells to destroy themselves.

They are using drugs and light to induce cancer cells to self-destruct. If successful, the experimental process could replace surgery now used to treat some tumors.

Although it is a novel conceptual approach to tumor treatment, manipulating cell metabolism is not new in cell biology, according to Kelley.

"We know how to kill a cell in many different ways. But, rather than injecting a chemical that kills cells, we have developed ways of modulating, destructively, cell metabolism," he said. "It opens a variety of choices and alternatives not presently available for phototherapy of cancer cells."

So far, the team has focused on interfering with metabolism of rapidly multiplying cancer cells in laboratory cultures. The next step will be to develop a model for testing the new approach on solid tumors.

"We know it works in the test tube. Now, we need to move to solid breast tumors, and if we are lucky, we may be able to inject a tumor with a solution of chemicals and a few hours later, treat it with a laser beam — no surgery — and achieve destruction of some tumor cells," Rebeiz said.

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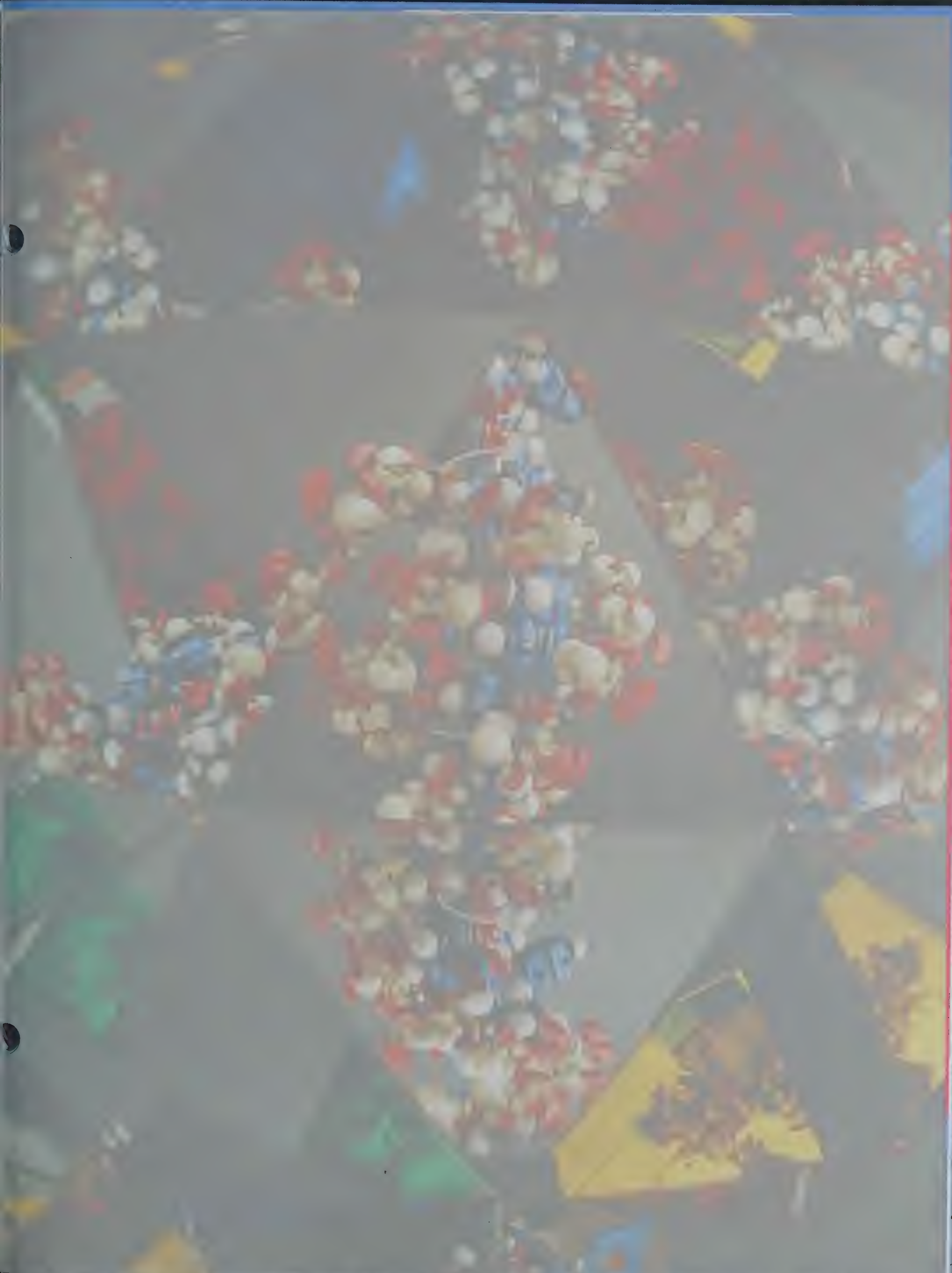

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Illinois Research

Fall 1991

STUDENT RESEARCH

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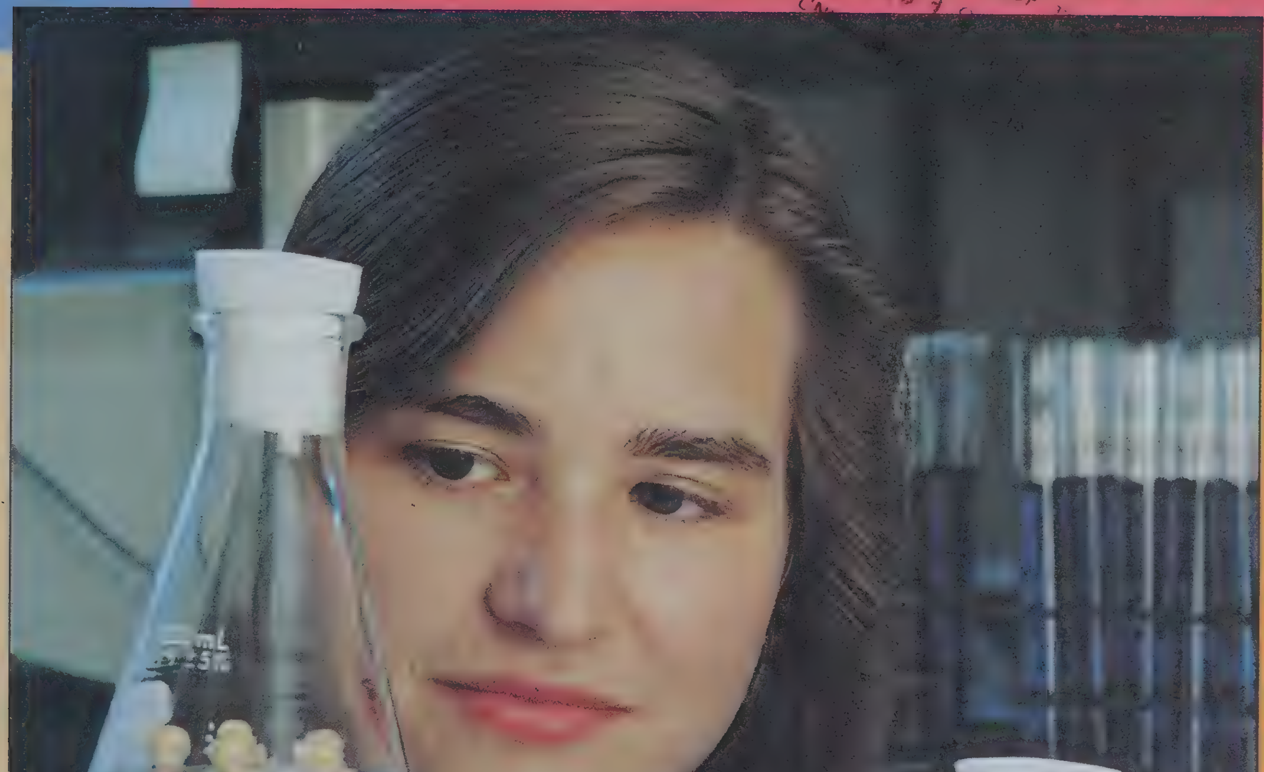

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 33, Number 3

THE COVER

Juliann Czyzewicz grows corn kernels in Erlenmeyer flasks to study how different nutrients affect kernel size, an important determinant of crop yield. See page 17.

At a time unlike any in the past, we must envision the future.

— Raymond G. Cragele, AES Director, 1978-1983

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Education for the Twenty-First Century

William L. George

These are exciting times. The world is in the midst of a technological revolution — one that is unmatched in human history and that will challenge our nation's economic growth and security for many years to come. For a century, the United States has led the world in developing science and technology on behalf of the global food and agricultural system. If our leadership is to continue, however, we must gain a broader understanding of the demographic, social, cultural, economic, and policy factors that influence agriculture.

We need a new generation of scientists who will lead the way in achieving breakthroughs in the rapidly growing fields of biotechnology. We need an outstanding cadre of scientists prepared to focus on genetics, molecular biology, physiology, biochemistry, and related areas. Similarly, future food and agricultural scientists and professionals must capitalize on opportunities to improve environmental quality, water conservation, food safety, and nutrition and health. We need to learn more about global climate change. And agribusiness managers and marketing specialists must help our nation regain a sure footing in the global economy. But these changes will not come easily.

Our scientific and professional expertise in the food and agricultural sciences is threatened on many fronts. Curricula

of colleges of agriculture are not popular choices among many of today's youth, even at a time when the job market for our graduates is excellent. There is serious concern about the lack of qualified professionals to fill positions. Moreover, the current food and agricultural sciences work force and student body suffer from a lack of cultural diversity. In many instances, gender diversity is also sorely deficient; graduate enrollments in some of our academic specializations remain predominantly male.

As we approach the twenty-first century, bold, innovative initiatives are needed to reverse the many factors moving us toward an eroding base of expertise in agriculture. We need new visions.

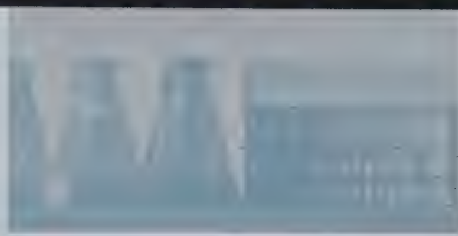
Our own College of Agriculture needs curricular revitalization. We need more balance between general education and specialized education to produce more rounded, *better-educated* graduates.

The College needs to sustain and expand its Jonathan Baldwin Turner (JBT) programs. Our JBT Merit Scholarship Program has attracted 719 outstanding student scholars to our College in twelve years. However, the program needs a stronger endowed funding base. Our JBT Undergraduate Research/Scholarship Program needs to expand so more students work with faculty in research and become inspired to seek advanced degrees. Our JBT Graduate Fellowship program, now a doctoral program, needs to expand to include master's degree students.

We need not only to improve access of our minority groups to quality education but also to ensure their success. We must increase our Minority Apprenticeship Program (MAP) for high school students, our Summer Research Opportunities Program (SROP) for minority undergraduates, and minority scholarships and internships. We need to develop minority graduate fellowships and assistantships and to enhance cooperation through student and faculty exchanges with historically black universities to enrich our minority pool.

By providing outstanding students with the means to investigate and understand societal problems, we will increase their professional competence. And we will prepare our students for the ever greater challenges of the year 2000 and beyond.

William L. George, Associate Dean and Director of Resident Instruction



The Complementary Relationship Between Graduate Student and Professor

Donald A. Holt and David H. Baker

Unlike undergraduates, who learn primarily by attending classes and studying textbooks, graduate students learn by doing. These more advanced students benefit most from conducting research over long periods in collaboration with an individual professor.

The close working relationship between the graduate student and his or her "major" professor adds a new dimension to learning. By the end of the experience, he or she has moved beyond the traditional student-teacher relationship to become the professor's colleague.

This form of individualized instruction is normally reserved for graduate students, partly because it is expensive. Selected undergraduates, however, also benefit from such hands-on research through innovative programs geared toward this group.

Graduate students are recruited, much like athletes. For practical reasons, each professor wants to work with the best and brightest students, who can contribute significantly to the professor's research program. More importantly, however, the students improve themselves as scientists so that they will be in demand in the job market when their degree is finished.

Graduate students bring a fresh, youthful vigor and creativity to their work. They are less biased by experience; they do not know what "cannot be done." Their generally high-quality work rarely has to be repeated. Catching the enthusiasm of science and discovery has a profound effect on their young lives.

Most professors feel that working one on one with bright, talented, highly motivated graduate students is the most rewarding part of their careers. It is also the most important way they influence their field of specialization, shape the future, and contribute to the welfare of humankind. Training the next generation of scientists is an important function of the university professor.

Relationships between professors and their graduate students range from formal and impersonal to deeply personal and even affectionate. In the College of Agriculture, it is rare when a graduate student does not develop a deep and lasting friendship with his or her major professor.

At first, the student is highly dependent on the professor. The professor must help the student select courses and a thesis topic. The student must be integrated into the structure and function of the professor's laboratory and research program.

Later, the student will begin to function more independently, taking more and more responsibility for selecting learning experiences and managing portions of the professor's program. As the student develops as a scientist, he or she may manage almost all day-to-day activities of the professor's program, thereby gaining valuable managerial as well as technical experience.

Effective graduate training takes the student from being an apprentice to becoming a master.

The professor ushers the student into the realm of scientific thought, in which all theories, hypotheses, and facts are subject to doubt, no matter what their source. The student must question his or her own ideas and judgments and must learn how to design experiments that attempt to disprove them. The student learns that intellectual honesty is the moral foundation of science.

Each student is set on a trail that can, and often does, lead to becoming the world's expert in a specialized field. To follow that unmarked trail, the student must learn in extreme detail the facts and procedures of his or her field and related fields. In addition, the student must use his or her own creativity to discover what lies beyond the known facts.

Effective graduate training takes the student from being an apprentice to becoming a master. Nothing is more rewarding to a professor than to nurture and watch that remarkable transformation.

Professors differ in their philosophy of graduate training and in their ability to train students. Some try to make the student over in their own image. Others help the student explore the full measure of his or her own creativity. Effective professors vigorously challenge students, instilling in them the philosophy that "if you want to float big ships, you have to go where the water is deep."

Successful research professors are under great stress to acquire outside fund-

Molecular geneticist Lila Vodkin, center, discusses data on soybean molecular biology with graduate students Joselyn Todd and Jon Lindstom. This kind of individualized instruction is typical of graduate training yet is enjoyed as well by a few elite undergraduates.

ing to sustain their program and pay the salaries of graduate students and other staff. Well over 80 percent of the cost of a professor's research program is offset by his or her own funding obtained from federal agencies and private sector grants. Ideally, graduate student trainees also obtain experience in writing research proposals. This ability will be essential to their success as researchers.

Graduate students also have to deal with stress. They are expected to perform academically and scientifically at the highest levels. The competition for positions is stiff. Only about one in eight applicants for graduate training are accepted. Students who were not in the upper 15 percent of their undergraduate class have little chance for success in the more rigorous graduate programs. Only about one in 400 people obtain a doctoral degree.

The rigor and competition of graduate training is necessary to prepare students for their careers. From the time they graduate with an advanced degree, their salary, rank, support, and job satisfaction will be almost directly proportional to their creativity, productivity, and capacity for hard work. Few will ever enjoy the protection of seniority. From the time they assume their duties as a professor or researcher, they will face the consequences of the rigorous promotion and tenure process or its private sector equivalent. Their salary will be based on merit.

In return for enduring the stress and competition, graduate students will enjoy the privilege of being modern-day explorers, stepping across frontiers into vast uncharted regions. To guide them, they will have only their own talent and ingenuity, tempered in the fire of graduate training and honed by experience.

Donald A. Holt, director, Agricultural Experiment Station; and David H. Baker, University Scholar and professor of nutrition, Department of Animal Sciences and Division of Nutritional Sciences

Disease Prevention Focus of Foods and Nutrition Research

Tina M. Prow

An interest in health and medicine, particularly disease prevention, drew Angela Odoms to the University of Illinois for a degree in foods and nutrition. The Chicago native said she expected to find her studies interesting and challenging, but she had no idea she would have an opportunity to help design and conduct an important research project before she graduated in 1990.

During her junior year, Odoms, 22, now a graduate student at Cornell University, was accepted into the UI Summer Research Opportunities Program (SROP). The program is designed to expose minority undergraduates to experiences they might have in graduate school. Hoping to make a contribution to the field of disease prevention through her project, Odoms chose to study the effects of alcohol on breast tissue.

"Breast cancer is a leading cause of cancer-related deaths among American women," she said. "Researchers have observed that women who drink moderately or heavily have a higher incidence of breast cancer compared with women who don't drink or who drink very little. I wanted to find out how alcohol may affect breast cancer."

Before she went into the laboratory, however, Odoms spent time in the library reading research articles related to alcohol, breast tumors in humans, and research procedures. She discussed the articles with her adviser, Keith Singletary, a UI nutritionist.

"I didn't know anything when I started," she admitted. But she was a quick study, according to Singletary.

"Angela was a genuine, diligent student — an eager learner able to comprehend new information in areas she hadn't had exposure to," he said. "And even though she lacked exposure, and hadn't taken certain science classes, she did an excellent job. Her observations appear to be valid and could be very important in giving us more clear insight into how alcohol may influence the development of breast tumors."

With an extensive literature review behind her, Odoms began the laboratory portion of the study. Using laboratory rats as an experimental model, she found that alcohol intake significantly increased cell replication in breast tissue. In a later study, she observed that alcohol slowed maturation of mammary glands, which could make cells in the breast more susceptible to the development of tumors.

"If someone gets the opportunity to do research, they should take it."

"To date, several studies have been done observing the relationship between alcohol intake and the risk of breast cancer in humans, but there hasn't been much research using an experimental model," Singletary said, "and that kind of research is important in clarifying and enhancing our understanding of this problem."

For Odoms, the research not only helped build the knowledge base for an area she was interested in, but also proved to be a fun learning experience.

"Everything went well. Dr. Singletary was a real inspiration; he took time with me when I didn't understand what I was reading, but also left me on my own to think through what I was doing. He provided the mechanisms for me to be independent, so I felt like I was in control and doing something important," she said.

Odoms' project did not end with laboratory observations. She also prepared a paper and made an oral presentation to the SROP advisory committee. Later, an opportunity to talk about her projects with fellow researchers at an annual meeting of the American Institute of Nutrition, a member of the Federation of American Societies for Experimental Biology, was a highlight of her research experience, she said.

"I prepared a poster and stood by it at the meeting to answer questions from people in biology, chemistry, and nutrition," she said. "There were a lot of scientists there; I had read some of their papers during my literature search, and it was exciting to talk with them."

The meeting was also an opportunity to talk with graduate students and faculty members from Cornell University. Odoms, currently a master's and doctoral candidate in nutrition and biochemistry at Cornell, plans to pursue a career in college-level teaching and research. Her undergraduate research experience, she said, helped her choose her goals.

Angela Odoms analyzes tissue samples with her adviser, Keith Singletary. Her research focuses on the link between alcohol consumption and breast cancer.

"If someone gets the opportunity to do research, they should take it. It's an opportunity to grow for the experience of learning," she said. "I feel that it helped me get more involved in the department and with an adviser, and that made me feel closer to people in the program.

"Also, I think going to national meetings and writing papers helps with the application if you're going on to graduate school. And once you're in grad school, which can be a terrifying experience — new classes, new people, a new place, and more work required — you aren't so unaware. You've already had some research experience, you've been in a lab, you know how to get papers, and you know some of the terms. A research project is an experience that's going to help in the long run with your graduate career."

Tina M. Prow, science writer, Agricultural Experiment Station

■

Students, Faculty Encouraged by Summer Research Program

Since 1986 the UI Summer Research Opportunities Program (SROP) has sought to encourage minority students to pursue academic careers. The evidence so far suggests that a little encouragement can go a long way.

Two-thirds of participants who have completed their undergraduate degrees have gone on to graduate or professional school, about three times the national average.

Many instructors who have served as mentors also have found encouragement — about the quality of research they can expect from undergraduates, and the role they as faculty members can play in lending support to a future scholar.

The program was launched six summers ago by the Committee on Institutional Cooperation — a consortium of Big Ten universities and the University of Chicago — as a means of reversing a decline in the number of qualified minority applicants to graduate schools. It encompasses all disciplines, including agriculture.

Its chief component is an in-depth research experience in which each student is matched with a faculty mentor who supervises the student's work.

To qualify for selection, the student must be either a sophomore or junior with a minimum 3.75 grade-point average. Each student receives a $2,500 stipend; each faculty mentor receives a $1,000 research allowance.

The program began in 1986 with 99 students, 10 at UI, and has grown dramatically since. This summer, about 600 students participated, with UI hosting the largest group — 90 students working with 83 faculty members.

As part of that growth, students have been invited in from outside the host institutions. Twenty-six of the 90 at UI fit that category, with most of them coming from six historically black campuses. The overall program is the largest of its kind in the nation, says Elaine J. Copeland, associate dean of the UI Graduate College.

William George, associate dean of the UI College of Agriculture and coordinator of College participation, says that 15 SROP students studied agriculture-related subjects this summer. Ten of those were supported through a $45,675 competitive grant from the U.S. Department of Agriculture.

Janice Bahr, a professor of physiology in the Department of Animal Sciences, has been an SROP faculty mentor for the past two summers.

"I think it's a very fine program," she said. "It's a wonderful opportunity for undergraduates to do research."

In 1990 Bahr, who runs a reproductive physiology lab, supervised biology major Donna Hemphill, whose project focused on ovarian function. Bahr said that the program has "opened up all kinds of doors" for Hemphill, who graduated in May and entered the UI Medical School in Chicago this fall.

A plus for the program, Bahr said, is that it gives support to the laboratory, which helps pay for expensive supplies. "The minute a student steps foot into your laboratory, [he or she] begins to cost you money," she said.

Bahr's support for the program is shared by her colleagues across campus. As one SROP mentor put it, "I just think the university has a jewel of a program here."

— *Craig Chamberlain, general-assignment writer, UI News Bureau*

Teenagers Demystify Sustainable Agriculture

Gary Bickmeier

Sustainable agriculture is making headlines in both the popular and agricultural press. The media has learned that the topic is controversial and pricks a nerve for many readers.

Emotion rather than knowledge seems to dictate opinion on this issue. The sustainable ag controversy is fueled by farmers' concerns for their children, health, and livelihood. It is also buttressed by the lack of research-based information and reliable, unbiased authorities.

To provide the agricultural community with better information and help quell fear and skepticism about sustainable agriculture, the Scott County Cooperative Extension Service in 1990 initiated a program of hands-on research for high-school students. Six 4-H and Future Farmers of America members planned and implemented on-farm research with the support of a grant from the Illinois Division of Natural Resources.

The teenage scientists delved into such topics as reduction and optimization of fertilizer, insecticide, and herbicide use, and enhancement of crop yield through integrated pest management. With the help of their parents or other adults, the fledgling researchers put out plots, took necessary tests (such as soil tests and nematode assessments), harvested the crops, and monitored results. Each student also made a presentation at a field day and prepared a research results paper.

Statistical analysis was emphasized throughout the project. The teenagers picked up the basic principles of analysis at two training sessions. Participants were exposed at every opportunity to

The author, left, accompanies students from Scott County on a tour of a research plot near the UI campus. Extension entomologist Kevin Steffey explains an experiment involving artificial infestations of black cutworms.

the requirements of a properly prepared, statistically analyzed research trial.

The teenagers learned firsthand of the troubles and tribulations encountered in agricultural research. Angela Worrell, a 13-year-old member of Liberty Hustlers 4-H Club in Winchester, got an unexpected surprise when ponded water wiped out a large section of one trial. Another youngster, Aaron Gregory, a 15-year-old Bluffs FFA member, gained a new appreciation for weeds after his postemergence herbicide study was thwarted by a lack of such intruders. Jill Stice, 16 years old and a member of the Scott County Eagles 4-H Club, lost some replication when her father picked corn and combined several replications on one weigh ticket.

Learning the value of statistical analysis the hard way, the participants and their families were thoroughly disappointed to find that of the six trials, only one had significant results. Most trials, however, were viable and well done but lacked adequate replications — something difficult to accomplish over the length of only one summer.

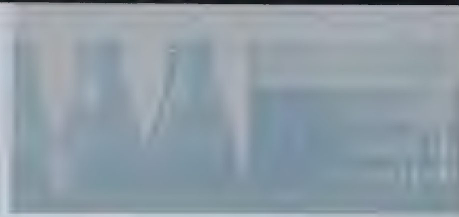
Eddie Mack Young, who assisted his son, Brad, a member of the Winchester FFA, commented, "I didn't realize how much precision is involved in ag research. After seeing the effort that was put forth on these plots, I can see why the amount of research from our colleges is limited." Jill Stice's father, Paul Stice, added, "After seeing what's involved in performing research, I find myself questioning manufacturers' claims even more closely."

As a result of the program, a large cross section of Scott County and other nearby residents got a closer look at sustainable agriculture through high school classroom sessions, plot tours, publication of plot results, and presentations at the field day.

The program has changed some attitudes, too. Help was given (perhaps grudgingly at first, but given nevertheless) by the Farm Bureau Board, Soil and Water Conservation District Board, and various businesses. Enthusiasm by members of these groups grew with every meeting. And in recent months, several members have come forward with their own ideas for sustainable agriculture programs.

The key to changing attitudes is knowledge — the more that is known, the less that is feared. Through the Scott County sustainable ag program, teenage researchers, their families, and friends are beginning to judge sustainable agriculture from a knowledge base rather than by emotion alone.

Gary Bickmeier, Scott County Extension adviser, agriculture



The Case of the Restless Researcher

Anita Povich

One sunny afternoon in Orlando, Florida, in 1987, Shannon Douglass accepted a luncheon invitation from the director of research at Ferry-Morse Seed Company in California. Douglass had just delivered a paper on her sweet corn research at the American Society for Horticultural Science meetings, and the director was anxious to meet her and discuss her research findings.

You could imagine Douglass's surprise when the director asked if she was happy with her assistant professor's position at the University of Illinois College of Agriculture. "Would you consider leaving to join Ferry-Morse as a seed physiologist?" he said.

"I'm just a student," the bewildered Douglass answered.

"Well," countered the flabbergasted director, "would you consider joining Ferry-Morse after you finish your Ph.D.?"

"But I'm only an undergraduate," Douglass laughingly responded.

This is a story that College of Agriculture Associate Dean William L. George likes to tell about Douglass, because it illustrates the success of the college's undergraduate research program.

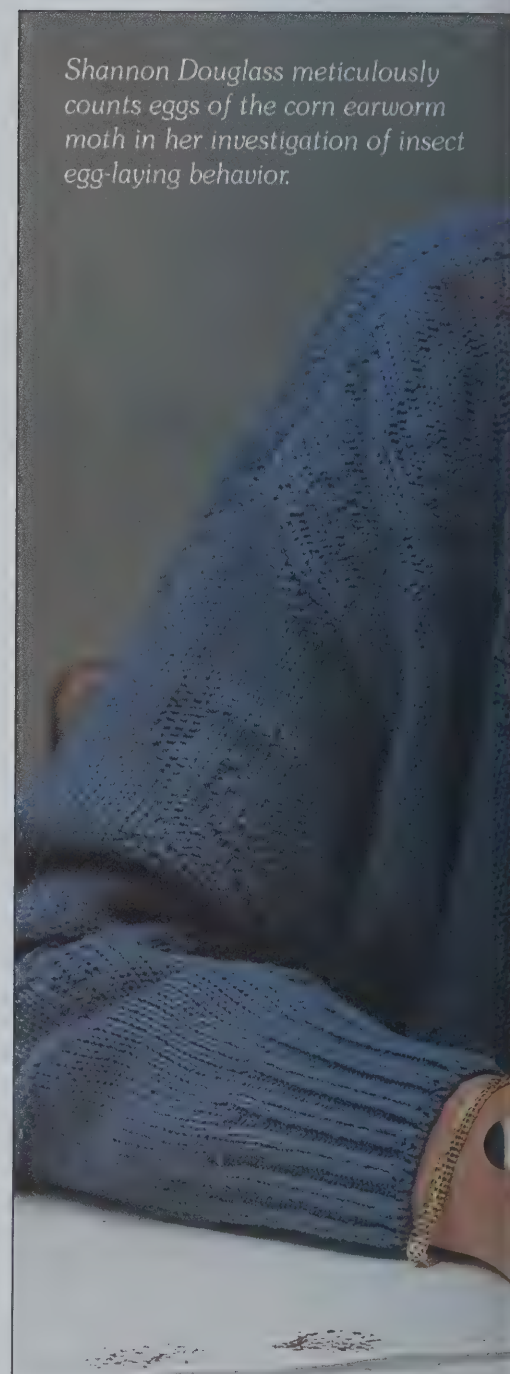
For although Douglass was only a junior when this story took place, she'd been an active researcher in the horticulture department for two years, thanks to the Jonathan Baldwin Turner Undergraduate Research/ Scholarship Program (JBT). Through the program, she was working on a major problem in sweet corn — germination and emergence in cold spring soils — with John A. Juvik, UI associate professor of plant genetics in the horticulture department.

Douglass is one of several dozen agriculture undergraduates given the opportunity to develop research projects with faculty and graduate students in the College. Her entry into undergraduate research was paved by George, who met her when she interviewed for a JBT scholarship in 1985. At that time, she was a dynamic and personable high school student recognized by George as someone "really interested in science and not intimidated by anything. She had a concept of science and the potential for solving problems that lent itself to undergraduate research," George says.

"She was looking at Cornell and the University of Wisconsin," George recalls, "but we wanted her at Illinois. She was among the best and brightest, an outstanding young woman who would welcome the opportunity to interact with faculty at a research level."

Although Douglass started her UI career as a horticulture major, she soon switched to agricultural science in order to take more chemistry classes, one of her favorite subjects in high school. "I loved chemistry," she says, "and studied it for three years. My teacher, Lee Borowski, was also my cross-country ski coach. In fact," she says with pride, "he recently won a national award for coaching the U.S. Olympic cross-country ski team."

Douglass graduated from Brookfield East High School, Brookfield, Wisconsin



Shannon Douglass meticulously counts eggs of the corn earworm moth in her investigation of insect egg-laying behavior.

(a Milwaukee suburb), with only one B among her straight-A grades. Tall (5'9") and muscular, she played soccer, volleyball, and basketball, and also edited the school yearbook.

Douglass was an impatient university student, eager to learn more. After completing her first year, she phoned George from her Wisconsin home to ask if she could work in a laboratory. He introduced her to Juvik, who eventually became her undergraduate and graduate adviser.

"Douglass was interested in plant breeding when I met her," recalls Juvik. "George sent her to talk with me, and we immediately put her to work."

Douglass has an interesting anecdote about her introduction to research in Juvik's laboratory. She fondly recalls Juvik telling one of the graduate students to give her a hard time because "she's one of the dean's special students."

Douglass doesn't feel "special," and is proud of her inquisitive nature. "I like to know why things happen," she says. "Research is like detective work."

She and Juvik proved a good match. "I ask my students to work on projects that have relevance to real problems in agriculture," Juvik says. "The reduced performance of sweet corn in cold soils is a big problem for the sweet corn industry. This was an excellent project for Douglass because it helped her develop an interdisciplinary approach — she worked both in the field and in the laboratory."

Douglass recalls working with sixty sweet corn genotypes for two years at two different locations in the state, measuring percent emergence, plant vigor, and uniformity. In the laboratory, she learned valuable analysis techniques, such as gas chromatography and spectrophotometry.

Her research experience ranged from "the mundane to the sublime" as she became familiar with methodology, Juvik says. "She was able to bridge disciplines at the biochemical and genetic level and apply her findings to agricultural problems.

"Her undergraduate research with the *shrunken-2* and *sugary enhancer* genes as she measured chemical characteristics in the lab revealed her love for pure research. Besides being an enthusiastic and effective worker, she's quite efficient at getting things done," Juvik says.

Douglass says that research taught her how to write a proposal, do a literature review, search for ideas, and consult with other researchers. "I learned to look at the data and ask why I'm getting these results."

After spending three years as a research assistant in horticulture and earning two JBT scholarships, a National Garden Club Scholarship, and an Orville G. Bentley Undergraduate Research Award, she received her bachelor's degree in 1989. Not long after graduation, Douglass designed her own master's project. She happened upon a research topic in plant biochemistry while surveying the host range of the corn earworm, *Heliothis zea*, one of the world's most costly plant pests. Her curiosity led to a topic that combined her love for both chemistry and plants.

In surveying the host range of ninety-nine different plants, she found that tomato and corn plants were especially attractive to female moths. She was curious about what made the insects prefer these plants for oviposition, or egg laying. Juvik's lab had already identified certain compounds in the tomato that attract the moth and stimulate oviposition.

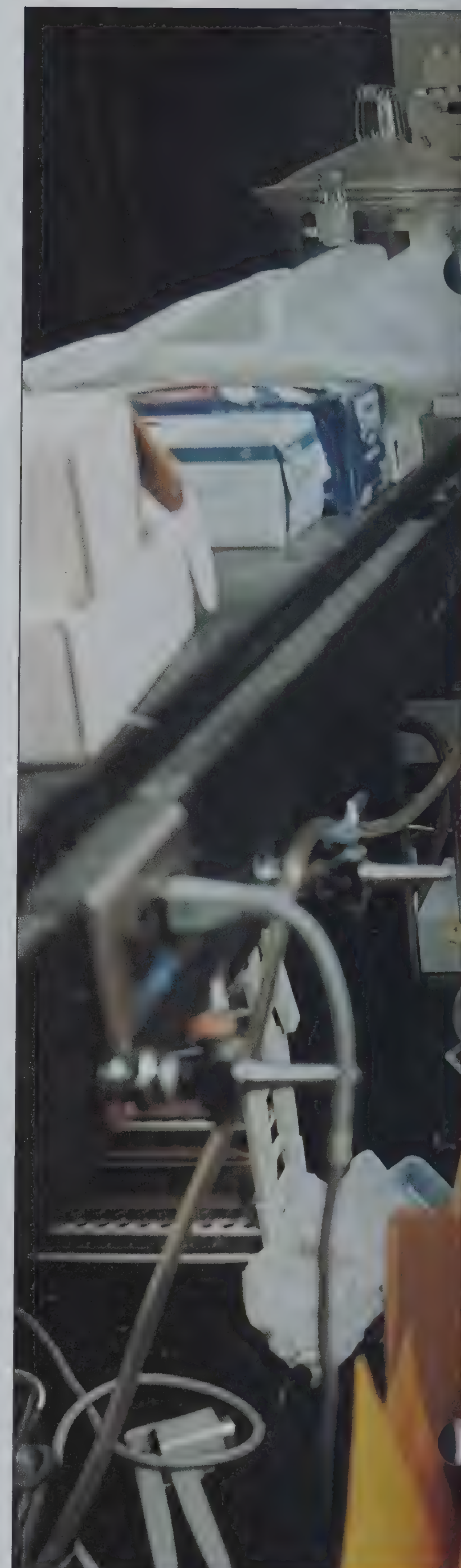
"Insects detect or choose plants by visual and chemical cues," Douglass says. "If we identify these chemical cues, we can encourage *Heliothis zea* to go to a weed, rather than a tomato plant, to lay its eggs."

This research reinforces the importance of identifying alternatives to pesticide use in order to reduce dependence on chemical pest controls. She studied the chemical structures needed to stimulate egg laying so that she could identify other compounds that elicit the behavior. She then designed a set of eight compounds and tested them for relative oviposition effectiveness by counting the number of eggs laid by the moths.

"Once you know the compound, you can develop a genotype with these features and have a control method," she says. During her research, she studied chemistry and ecology to learn more about plant chemicals and natural product biology.

Although Douglass spent hours and hours in the laboratory, usually 8 a.m. to 10 p.m. during the work week, she found time to play with the UI Soccer Club and watch her favorite soap operas on an old black-and-white television that she kept at her desk. Understandably, one of her goals after graduation was to earn some money after living on a graduate student stipend that ranged from $6,000 to $8,000 per year. She names Robert Frost as her favorite poet, and sees his lines, "and miles to go before I sleep, and miles to go before I sleep," as symbolic of her life in research.

This past year, 23-year-old Douglass made several changes in her life. On January 17 she successfully completed her master's thesis. On February 16 she returned to Brookfield, her home town, where she married Scott Campbell, a UI computer engineering graduate. And on March 18 she began her research-and-development position in Colgate-Palmolive Company's oral-care division, working with toothpaste. In hiring her, the vice-president of global product development said that "she'd be a good fit,



During the research project, Shannon Douglass spent most of her waking hours in the lab. With her is plant geneticist John Juvik.

she has a real science mind," and "her presentation to staff during the interview was the best we'd ever had."

Douglass says that she welcomes the competitive nature of private industry. "I grew up in an extremely competitive family where my brothers and I always competed for grades. Steve, 25, is a nuclear engineer with the Navy, and Ryan, 20, is a physical education major at the University of Wisconsin–La Crosse.

"Competition is a good motivating factor," she reveals, "but it wasn't always good for my self-image."

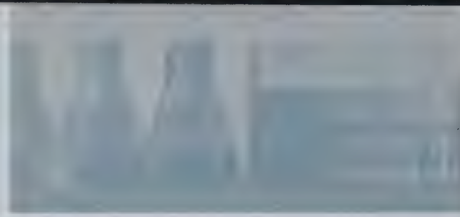
In person, Douglass is shy, reluctant to discuss her achievements. And they are numerous. She completed her UI studies with only a couple of B's and the rest A's after five and a half years of research in horticulture. She was on the Dean's List every semester, and numbers fifteen honors and awards on her resume, including the prestigious Bronze Tablet, the highest undergraduate honor. She's currently the author of seven research papers, two of which are published in trade journals. Yet this serious researcher describes herself as sometimes loud, sometimes obnoxious, and very stubborn.

Her UI professors disagree with her self-assessment.

"Douglass is unusual in that she's among the upper 3 to 4 percent academically," George says. "She's dedicated, has perseverance, and followed a rigorous curriculum throughout her bachelor's and master's degrees. She's at the forefront of scientific investigation, thanks to her abilities and her introduction to challenging agricultural research."

Her adviser, Juvik, whose laboratory received a $200,000 grant to continue Douglass's undergraduate research project on cold tolerance in sweet corn, describes her in a simpler fashion: "She has a big research appetite; she'll do fine."

Anita Povich, agricultural publications editor



From Dishwashing to Lipids

Doug Peterson

It started with dishwashing and ended with some award-winning research on an innovative new piece of food chemistry equipment.

As a University of Illinois undergraduate in food science in 1988, Dena Miller was looking for some extra spending money and a chance to observe what goes on in Burnsides Research Laboratory. So she took a job washing fats and oils out of test tubes and other lab glassware.

Within a semester, Miller's resourcefulness took her into the Jonathan Baldwin Turner Undergraduate Research/Scholarship Program. Through the program, she remained in Burnsides Laboratory, but this time she was the one putting oils *into* the tubes, rather than cleaning them out. She began doing work on lipids, which include both fats and oils and are found in a variety of foods.

From a health perspective, polyunsaturated fats are a healthier choice than saturated fats, which are linked to increased heart disease. The drawback, Miller says, is that polyunsaturated fats are much less stable than saturated fats. They go rancid faster, leading to off-flavors.

"When fats are exposed to light and oxygen, they begin to decompose," says Ed Perkins, a UI professor of food chemistry and nutritional sciences, as well as Miller's research adviser. "The question is, how long can you store fat or oil before it goes rancid?"

To measure how quickly various fats and oils go rancid, the food industry has traditionally relied on the active oxygen method (AOM), which Miller says is "a very tedious, labor-intensive method."

That's why the Archer Daniels Midland Company in Decatur has developed a new technique — the oil stability index (OSI). This automated approach removes much of the tedium and saves labor.

Miller's job was to work with one of the two OSI prototypes in existence. She put the equipment through a battery of tests to see how it stacks up against the traditional active oxygen method.

After testing three different soybean oils with the OSI prototype, Miller says they found that the new approach was a clear success, for it "correlates quite well with the older method."

The project went smoothly, she says, except for the usual equipment headaches and a surprise flood in the lab room. Water used as a coolant overflowed during one night and coated the floor by morning.

But glitches or not, this kind of research gave Miller a foretaste of graduate school, preparing her for the master's degree work she is now pursuing in food science at Cornell University.

"As an undergrad working on this project, I put in ten to fifteen hours of work per week," Miller says. "I felt like a graduate student, working at the lab until midnight and on Saturdays. This research taught me to think on my own and work independently."

"It took a lot of dedication for her to come in here every day," says Steve Hill, a UI graduate student in food science who helped supervise Miller. "Most undergrads don't even step foot into this kind of lab — a cross between organic chemistry and food chemistry."

"It's unique to have an undergraduate do scientific research...period," adds Perkins.

The inquisitiveness that drew Miller into Burnsides Lab goes back to her life on a farm near Niantic, Illinois.

"I was always reading food labels," Miller says. "In high school, I was always wondering how my father's corn made it into a box of cornflakes. I wondered how cheese puffs puff. I wondered what potassium sorbate was. And I liked to cook and experiment."

During her undergraduate career, Miller didn't exactly get an inside look at how her father's corn makes its way into a box of cornflakes. But she did get a good look at how low-calorie ingredients are made, how corn sweeteners influence product shelf life, and how cocoa processing affects pudding texture and flavor.

Those unique perspectives came from summer internships at three different food companies — the R.J.R. Nabisco Company in New Jersey, A.E. Staley Manufacturing in Decatur, and M & M Mars Inc., in New Jersey. As an intern, she sampled everything from the formal, suit-and-tie environment of Nabisco to the looser, more informal life at a candy company.

"They gave us interns a surprising amount of responsibility," Miller says.

On-the-job intern experience nicely complemented her research experience in Burnsides Lab. And topping it all off was a healthy amount of recognition.

In 1990, Miller's work with the OSI

Through hard work and determination, Dena Miller rose to the rank of researcher.

prototype earned her second place in the College of Agriculture's Orville G. Bentley Undergraduate Research Award program. In addition, the Institute of Food Technologists (IFT) chose her research paper as the best among Midwest undergraduates. And at the national IFT conference in Anaheim during June of 1990, she took second place with her presentation.

At Cornell, Miller is continuing her emphasis on "lipid oxidation" — the process that causes some food to go rancid. In particular, she is looking at the effect of dietary iron on pork.

"Because pigs are susceptible to anemia at a young age, hog producers often overshoot the level of iron that they put into a pig's diet," she says. "As a result, more iron is found in the meat. We're looking at how this affects lipid oxidation — how it affects the speed at which the meat goes rancid."

Miller has had a knack for charting a straight course in her career. She chose food science as her major during her first year at the UI and has not diverted from this track. She now hopes to complete a doctoral degree, then land a job in industry in research and development.

This time around, however, she'll skip the dishwashing job.

Doug Peterson, Extension communications specialist

Selling Young People on Science

Orville G. Bentley

Many agriculture colleges have, to their credit, provided undergraduate students opportunities for exposure to research. Such experiences frequently lead the students into careers as science teachers or scientific researchers. But the anticipated demand for more highly trained people in the future, especially in science and technology, is greater than can be supplied by students now in the science-education pipeline.

Erich Bloch, former director of the National Science Foundation, recently stated his concern about the decline of science education in an article published in the journal *Science*: "We are not mobilizing the human resources we need to compete effectively in a modern world." Further, "our high schools offer too few science and mathematics courses,...student interest in science and engineering is declining,...and only about 15 percent of college freshmen plan a major in science or engineering."

A former president of the American Association for the Advancement of Science, Richard Atkinson, adds that future shortfalls in the number of trained scientists and engineers "will have a major impact on economic growth, international competitiveness, and national security." (See graph.)

Obviously, educational institutions need to be actively searching for new ways to persuade students to pursue science as a career. The UI College of Agriculture is doing just that.

The College is stirring up interest in science by giving undergraduates a taste of research normally reserved for graduate students and professional scientists. The Jonathan Baldwin Turner Undergraduate Research/Scholarship program (JBT), for example, involves the selection of undergraduates on a competitive basis to develop research projects and carry them out in consultation with their faculty and scientific advisers.

After the research is finished, reports on their projects are judged by a college-level committee as a basis for recognizing the quality of their work. The winners are recognized by receiving the Orville G. Bentley Undergraduate Research Award, which carries a cash prize that has varied from $50 to $250. Over the past eight years, eighteen students have received such a prize.

An impressive outcome of the JBT and Bentley awards programs has been the selection of thirty-eight research reports for presentation at national or state scientific meetings. Few undergraduates ever receive such recognition. To top it off, twenty-three reports have been or will be published in scientific journals as papers or abstracts.

The breadth of the students' research is equally impressive. Topics have included nutrition, soil fertility, farm management, animal science, agronomy, food science, and home economics.

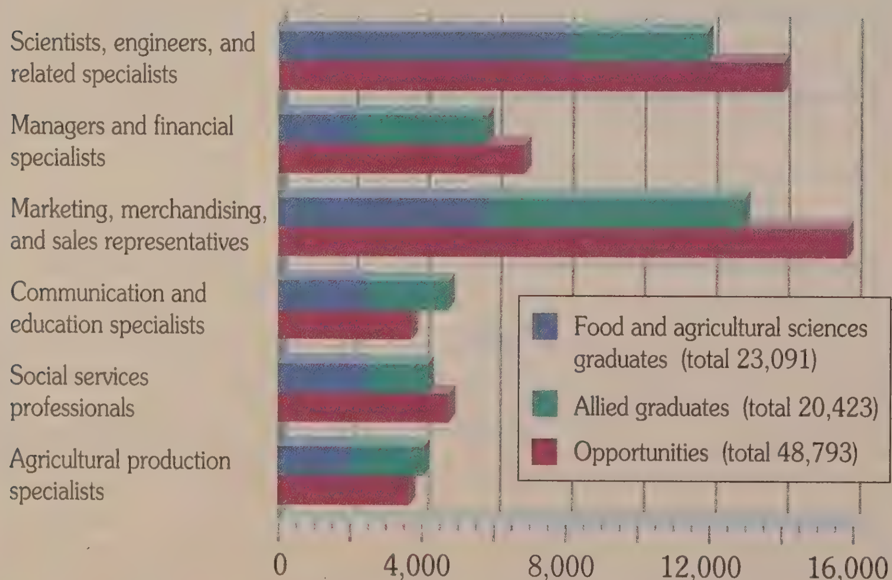
Research provides undergraduates a hands-on opportunity to "put education to work." Further, it introduces the student not only to research methodology but also to the discipline needed for evaluating and reporting data.

The College's effort to steer more students toward science careers seems to be working. Nearly all of the students who have received the Bentley undergraduate research prize and have earned their degrees are now employed in science-related positions or have entered programs for graduate education in science.

Agriculture educators across the country have a challenging opportunity to encourage students to seek productive and rewarding careers in agricultural science and education. One way to do so is through programs such as the JBT research awards and the Bentley prize. The potential benefits will be to enhance the competitiveness of U.S. agriculture domestically and in world commodity markets and to develop the scientific and technological leadership needed for the future.

Orville G. Bentley, dean emeritus of the College of Agriculture

Annual Graduates and Employment Opportunities in the Food and Agricultural Sciences, 1990–95



Source: U.S. Department of Agriculture. 1990. *Employment Opportunities for College Graduates in the Food and Agricultural Sciences.* -Food and Agricultural Careers for Tomorrow, Purdue University.

A Glimpse into the Lives of Three Young Researchers

Nancy Nichols

No two scientists think exactly alike. Even when doing research in the same field, using similar laboratory techniques, and conforming to the same rigorous standards, scientists differ in how they organize and carry out their experiments. Each takes his or her own path toward discovery.

The following profiles show similarities and differences among three young researchers at the University of Illinois. Each earned a College of Agriculture degree and, in the process, conducted scientific research through the Jonathan Baldwin Turner Undergraduate Research/ Scholarship Program. But the diverse topics they chose to study — wool, corn, and restaurants — reflect their distinct personalities, backgrounds, and professional interests.

Renita Jones Jinkins

Age: 21.

Hometown: Greenup, Illinois.

High school: Cumberland.

Achievements in high school: Class valedictorian; Illinois Future Farmers of America degree; FHA chapter president; National Honor Society secretary; Cumberland County 4-H secretary.

Agricultural background: Parents own 120 acres of tillable farmland; raised sheep as a hobby.

Current status: Bachelor's degree from UI in textile and apparel marketing (December 1990); working on doctoral degree in textile science at the University of Georgia.

Undergraduate research topic: Selected properties of crossbred lamb's wool.

Why I do what I do: "I was in the UI honors program, and they have a big push toward research. Once I got into wool research, I decided it was something I really wanted to do."

Career plans: "In the short term — in my Ph.D. program — I'd like to look at fabric 'hand' and drape, for which there seems to be a very direct application. In the long term, I want to teach and do research at a university, and eventually become dean of a home-economics department."

Distinctions at UI: Orville G. Bentley Undergraduate Research Award; Chancellor's Scholar award; Phi Upsilon Omicron National Scholarship.

Latest accomplishment: American Home Economics Association national fellowship.

Favorite place to study: In the agriculture library carrels, "where no one can see you."

Favorite animal: Corriedale sheep.

Last book read: *It's Always Something,* by Gilda Radner.

Favorite publication: *Ms.* magazine.

Interests: Sewing, walking, volleyball, backpacking.

Favorite musician: Clint Black.

Favorite movie: *The Sound of Music.*

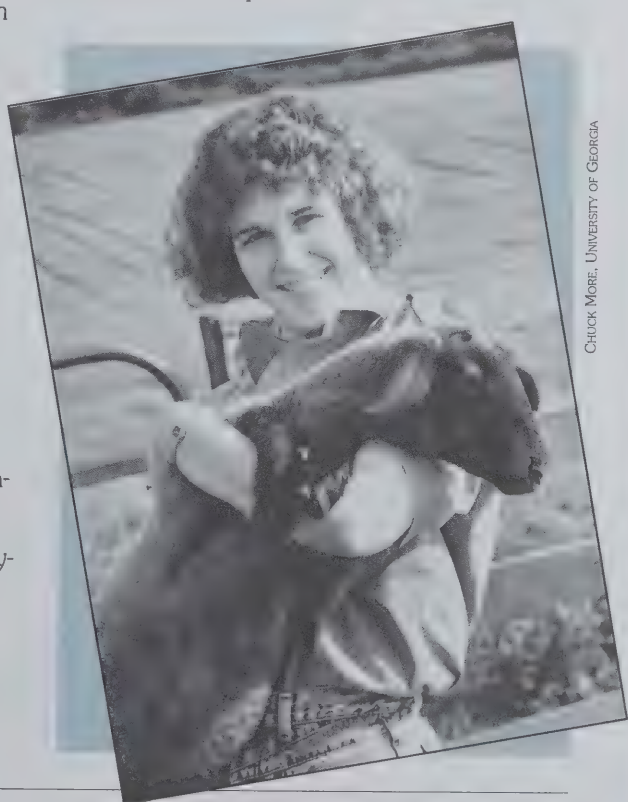
Favorite food: Italian.

Favorite place in Illinois: Parents' home.

Favorite place outside Illinois: Northeast Georgia mountains.

Greatest lesson ever learned: "That you don't have to give 100 percent all the time, that you're not able to give 100 percent all the time. There are only so many places you can spread yourself. Not everything can get equal attention."

Thoughts about creativity: "For inspiration, usually I go off by myself. Sometimes I sit up in the textiles lab, like at 11 or 12 at night. I figure that if I'm in the textiles lab, maybe I'll get vibes coming in that will inspire me."



Chuck More, University of Georgia

JOHN ROSSI

Age: 22.

Hometown: Chicago.

High school: Marist.

Achievements in high school: "To be terribly honest, I was a very average student in high school. I was on the wrestling team for a couple of years, but most of the time I worked. All the children in my family pay for their own schooling."

Agricultural background: Urban gardening.

Current status: Bachelor's degree from UI in restaurant management (May 1991).

Undergraduate research topic: Consumer preferences for beef and pork products served in restaurant buffets.

Why I do what I do: "Since I was 12 years old, I have loved to cook. When it came down to choosing a career, I asked myself, Well what do you really enjoy doing?, and it was food. I also enjoy business, and my first intention was to study business. I've been able to combine the two with restaurant management."

Career plans: To take a year or two off before attending law school, eventually becoming a legal consultant for restaurants.

Distinctions at UI: George M. Pullman Educational Award; Jessie Fox Kinnear Scholarship; Illinois Restaurant Association Award.

Latest accomplishment: Bronze Tablet award (highest UI undergraduate honor).

Favorite place to study: "The stacks in the graduate library, where there are just floors and floors of old books that hardly anyone reads. You can hide in there very easily."

Favorite restaurateur: Jean Banchet, former owner and master chef of Le Francais restaurant in Wheeling, a Chicago suburb. "Excellence was all he would settle for. If it could be done, he did it. If it wasn't going to be perfect, he wasn't going to do it."

Most memorable moment in college: Getting locked in the graduate library stacks at night during finals week.

Second most memorable moment in college: Getting locked in the undergraduate library stacks the next evening.

Favorite animal: Dog.

Favorite plant: *Crocus sativus* (saffron).

Last book read: *The Firm,* by John Grisham.

Favorite publication: *Gourmet* magazine.

Hobbies: Fishing, hunting.

Favorite music group: Genesis.

Favorite movie: *The Godfather*.

Favorite food: Italian pastas.

Favorite restaurant: Spiagia in Chicago.

How I spend my spare time: Reading cookbooks; cooking at home for the family.

Favorite place outside Illinois: Milwaukee, for its zoo and its marvelous German restaurants.

Thoughts about creativity: "To me, creativity calls to mind the kitchen. It's probably the only place where I am particularly creative. I consider what I do in the kitchen to be art."

JULIANN CZYZEWICZ

Age: 25.

Hometown: Niles (northwest Chicago suburb).

High school: Niles North in Skokie.

Achievements in high school: Captain of the swim team and member of diving, gymnastics, and soccer teams; clarinet player in band; member of the Environmental Club.

Agricultural background: "Being a city kid, I didn't even know what agronomy was."

Current status: Master's degree from UI in plant physiology (May 1990); working in UI agronomy lab studying nitrogen fertilizer's effect on corn kernel and cob development.

Undergraduate research topic: *In vitro* identification of factors governing seed size in corn.

Why I do what I do: "I did well in high school in science. It's monotonous work and it's boring, but I've been brainwashed — I love it."

Career plans: "To be a famous scientist. To me, that means learning more about the workings of a plant — discovering the best environment and nutrients for a plant to grow in."

Distinctions at UI: First place Orville G. Bentley Undergraduate Research Award; Mable Hunter Award; second-place photography award from American Society of Agronomy.

Latest accomplishments: Getting master's degree; bowling high game of 217.

Favorite animal: Cat.

Favorite plant: "Of course it's corn. I live corn. I breathe corn."

Favorite TV show: "Cheers."

Last books read: *Socrates Meets Jesus,* by Peter Kreeft; *Chronicles of Narnia,* by C.S. Lewis.

Favorite publication: *Science News.*

Hobbies and interests: Bowling; singing; playing flute and clarinet; photography; psychology; throwing "Christmas-in-July" parties.

Favorite music groups: Chicago; Michael Card.

Favorite movie: *Dead Poets Society.*

Favorite food: Naleśniki (Polish crepes).

Favorite restaurant: Walker Brothers on Chicago's North Shore.

How I spend my spare time: Directing a church choir and putting together jigsaw puzzles.

Favorite place outside Illinois: Dubuque, Iowa; "big caves" anywhere.

Greatest lesson ever learned: "No matter how many factors in the environment you control — the light, the water, the temperature — the plant will do whatever it pleases."

Thoughts about creativity: "Problems I see inspire creative thinking on how to solve them, from small problems in the lab, like how to go about setting up an experiment, to large problems like feeding the world. I usually do my creative thinking either on my bedroom floor or at my office desk, with classical music in the background."

Nancy Nichols, agricultural publications editor

Improved Embryo Preservation Process for Livestock Industry

Tina M. Prow

Growing up on a beef cattle farm in Williamston, Michigan, Christine Simmons was used to working with animals. In fact, she grew up thinking she might be a veterinarian. So she was a little surprised by her reaction during her first encounter with laboratory mice at the University of Illinois.

"I really had to work at getting to where I could handle them," said Simmons, 22, a 1990 UI graduate.

Becoming comfortable with mice was only one hurdle that Simmons, now a graduate student at Michigan State University, overcame while she pursued a degree in animal sciences at UI. Without any experience in laboratory research, she undertook a project and developed the skills to accomplish results that will help scientists in their efforts to refine techniques for long-term freezing and storing of embryos.

"After I took the regular animal science classes, I wanted to do something else. But there were no other classes for undergraduates," she said. She took her problem to Charles Graves, one of her instructors, and he suggested research under the Jonathan Baldwin Turner Undergraduate Research/Scholarship Program.

Her successful proposal outlined a study of problems associated with vitrification, an experimental method for fast-freezing of embryos by placing straws containing embryos directly into liquid nitrogen (-196°C) rather than slowly decreasing temperature during the cooling process. A new technique, vitrification was first used in a laboratory in 1985. During the vitrification process, embryos are placed in a fluid and cooled very rapidly to a solid without the formation of ice crystals.

"Christine committed many evenings and weekends to her work and displayed

Jamie DePolo, Michigan State University

Having grown up on a cattle farm, Christine Simmons feels at home in the research barns.

"The research also has larger implications. Someday, it may be possible to preserve large organs, such as the heart, in a similar manner."

dedication, self-discipline, and interest," said Graves, a UI animal physiologist and Simmons' research project adviser. "Her work has enabled us to greatly improve the technique for freezing and storing embryos, which has important implications for the livestock industry."

Already familiar with artificial insemination procedures on the farm, Simmons envisioned a similar low-cost process for storing and then transferring embryos to recipients. Her research project focused on preventing cell-damaging ice crystals, common in the slow-cooling process, from forming in embryos. But her first problem was to find a way to do the research.

"There were a lot of little things I had to do before I got started — find the equipment, make the medium for freezing the embryos, and even develop my own skills in handling petri dishes and cultures and microscopes. It took a lot of time, and not everything worked right the first time or worked as I thought it would," she said. "But along the way, I picked up the skills I needed and found the factors I wanted to look at; the preparation proved to be one of my most valuable learning experiences."

After she developed a system for conducting the studies — and established a rapport with the mice — Simmons devised control studies based on findings reported in literature and parallel studies that varied temperature and time factors.

She found that storing embryos more than 24 hours before vitrification decreased survival compared to embryos stored less than 24 hours or not at all. Embryos cooled to 4°C before being placed in a protective fluid had better survival rates than the controls, which were added to a protective fluid at 25°C. Similarly, embryos equilibrated in fluid for 5 minutes had better survival than control embryos kept in fluid for 10 minutes. A sucrose solution added during thawing to slow removal of the cryoprotective medium from the embryos decreased embryo survival.

"This is an important technology for improving production efficiency and cost on the farm," Simmons said. "With the success of the smaller animal embryo systems, it's just a matter of time before a producer or veterinarian is able to retrieve embryos, freeze them, and then implant them into the recipients at any time, just as they do with artificial insemination now.

"But the research also has larger implications. Someday, it might be possible to preserve large organs, such as the heart, in a similar manner."

Simmons had an opportunity to discuss her findings with other scientists during the 1990 National Animal Science Meeting, where she presented the first of two papers to come from her research. That same year, she also presented a poster at the Midwest Animal Science Meeting and made an oral report to the College of Agriculture's JBT Undergraduate Research Committee.

"The research project helped me decide what I wanted to do after graduation. I had applied to vet school, but because of that whole experience with research I decided to go to graduate school instead," Simmons said. She is earning a master's degree in reproductive physiology at MSU, trading laboratory mice for the more familiar cattle to study the effects of bovine somatotropin during dry and lactation periods.

Simmons said her plans include working on a doctoral degree and pursuing a career in research, possibly with industry or combined with teaching at a university.

Her success and interest in research have come as no surprise to her UI academic adviser, Douglas Parrett. Parrett, a beef cattle researcher, met Simmons when she showed cattle in high school. Even then, she struck him as "extremely bright, personable, and full of potential," and he took every opportunity to talk with her about academic and research opportunities at UI.

"From the beginning, Christine exhibited excellent academic skills. She was interested in science and really fit the mold for research," he said. "But at the same time, she wasn't a bookworm — she's outgoing and was able to find time to be active in her sorority, student clubs, and other extracurricular activities.

"Christine is a rare find."

Tina M. Prow, science writer, Agricultural Experiment Station

Keeping Up with a Changing Work Force

Kandeh Yumkella

Our food and agriculture system has advanced dramatically in recent years. Breakthroughs in biotechnology are meeting the demand for better agricultural products. Redesigned crop production methods are becoming more friendly to the environment.

Although the new technologies are getting the fanfare, the workers who will be using the technologies are equally important. In the future an increasing number of those workers will be minorities.

By the end of the decade, 85 percent of all new entrants into the U.S. work force will be women, minorities, and recent immigrants. These demographic shifts also affect the public school system. In the year 2000, minorities will constitute more than 40 percent of the enrollment in many public schools in major U.S. cities.

As our economy becomes more sophisticated and technology-oriented, and as competition in international markets increases, the need for highly trained minority professionals will be great. Our competitiveness in the global marketplace will hinge to a great extent on the contributions that these future technicians and managers make to the national product.

Recognizing this urgent need, the UI College of Agriculture is intensifying its efforts to recruit minority students to both undergraduate and graduate programs. In the 1980s, several initiatives were undertaken through the Minorities in Agriculture Program to vigorously recruit minority students and retain them. The goal has been to increase the number of minorities in food, agricultural, and human-sciences curricula. It is hoped that these students will form a pool of qualified minorities for faculty or professional positions in academia, government, and industry.

One of the initiatives to recruit and retain such students is the Minority Apprenticeship Program (MAP). This six-week program is jointly administered by the College of Agriculture and the College of Veterinary Medicine. It targets students who have completed their junior year in high school and is designed to expose the student to scientific research, careers in the food and agriculture industry, and college life. Since its inception in 1987, MAP has had seventy-seven participants (twenty-three in 1988 and 1989, and thirty-one in 1990).

The students receive hands-on experience working with faculty and graduate students in such areas as tissue culture, DNA coding and fingerprinting, food processing and engineering, nutritional analysis of food products, and microcomputerized video-imaging. In addition to their daily research responsibilities, MAP participants are also involved in computer instruction, career awareness sessions, and field trips.

The students submit weekly reports about their work, and at the end of the program they prepare a write-up of their research. A panel of judges selects the three best research reports, and the authors are asked to present their work at a farewell luncheon attended by College administrators, faculty mentors, and donors. All participants receive a stipend and a certificate of recognition.

MAP has been an effective recruiting tool. In 1989, 36 percent of the minority members of the College's freshman class were former MAP participants. Thirteen of the twenty-seven students admitted for fall 1991 have participated in the summer 1990 program. And sixteen students in the first two graduating classes from the Chicago High School for Agricultural Sciences have enrolled in the College of Agriculture. Each year several other MAP participants have enrolled in agriculture programs at other universities.

> By the end of the decade, 85 percent of all new entrants into the U.S. work force will be women, minorities, and recent immigrants.

The vast majority of financial support for the program has come from nonrecurring funds from individual departments in the College, the U.S. Department of Agriculture, and the National Institutes of Health.

Several agriculture-related companies have sponsored students interested in certain disciplines. These sponsors have included John Deere, Nutrasweet Company, Archer Daniels Midland Foundation, and Nabisco Brands. Other companies, such as Monsanto Agricultural Company, Caterpillar, and Frito-Lay, have given facility tours to program participants.

MAP participants have given the program rave reviews. Lebecca Gills, a 1990 participant from Rich East High School in Park Forest said that the strength of MAP was that it gave the students an insight into what they took for granted. "As I learned more about agriculture," said Gills, "I realized it was not just for farmers."

Another student, Natasha Buckner of the Chicago High School for Agricultural Sciences, said that visiting agriculture-related companies and learning more about computers were the most exciting parts of the program.

The College continues to vigorously seek funds to expand and improve MAP. A math enrichment class has been introduced for second-time participants who have also been admitted into the College. And plans are under way to expand participation in coming years.

The biggest strength of MAP is that it gives minority high school students a chance to experience college life. Getting a college education and studying agriculture become viable options for their "life after high school."

Kandeh Yumkella, assistant to the dean for minority affairs

Gene Research to Help Animal Breeders

Claudine Cole

This spring, a University of Illinois junior began an experiment that could lead to exciting applications in the livestock industry.

Allan Kaspar, a recipient of the Jonathan Baldwin Turner Undergraduate Research Scholarship (JBT), is conducting a gene research experiment that could provide more dependable information for animal-breeders to use in selection. The experiment involves studying genes that influence growth.

The agricultural science major's excitement about his research is obvious as he describes the project. "I've never experienced discovery," Kaspar said. "I'm most excited about the fact that it gives me a head start" on getting into graduate school.

"I could go all four years, get straight A's, and never 'do science'," he said.

Since his freshman year, Kaspar, 20, has helped out with other researchers' experiments in the laboratory of his adviser, Larry Schook. But just "hanging around," as Kaspar calls it, had in some ways been frustrating. "Procedures are time-consuming. One little experiment can take a week," he said. "So I missed out on parts of the process," including seeing the result of some experiments.

Now that he is in charge, the situation is different.

Kaspar's experiment can be worked on for two to three hours a day and then left, said Schook, a UI professor of animal science. It should allow Kaspar to see the "big picture" over a long period of time.

The junior's motivation for applying for the JBT scholarship, which provides

Allan Kaspar examines cells through a microscope in the molecular immunology lab.

$1,000 for lab costs along with a $500 tuition reduction, partly stemmed from his wanting more explanation than classes give. "That's not real experimentation, when you know what the results are going to be already," Kaspar said with a laugh.

He first became interested in studying biotechnology while still a student at Pleasant Plains High School in his hometown of Springfield, Illinois. Besides studying basic genetics in a biology class, Kaspar said he also spent time reading intriguing news reports about early field tests of engineered bacteria and other feats of biotechnology.

During his three years at UI, he has received the Raymond J. Fitzpatrick Family Scholarship for demonstrating interest in agricultural environmental problems and their solutions. He also has won a Colgate-Palmolive Undergraduate Laboratory Research Award from the Biotechnology Center.

Kaspar's project involves studying genes related to growth and the point at which they are expressed in the development of mice embryos. Specifically, genes that influence muscular development and weight gain are being analyzed, along with about eight others that influence growth in some way.

Schook said the results should help livestock breeders by showing at what point muscular development and weight gain can be manipulated in animals. Embryos are already screened in the dairy industry for the presence of a certain form of casein, a protein in cows' milk that is necessary for cheese production.

Schook said the screening could save money by eliminating less-efficient animals, something every producer hopes for.

Hands-on lab experience helps undergraduates like Kaspar get accepted into top graduate programs.

But Schook hastens to add that the main purpose of the experiment is to provide Kaspar the opportunity to do research himself. He said the project has made Kaspar — who plans to study cell and structural biology in graduate school — more committed, less nervous, and more independent.

How does Schook, a senior faculty member, feel about working with undergraduates? "Oh, it's great!" he said. He enjoys introducing them to research, making them competitive graduate school candidates. Graduate programs want to see the distinction of years in a lab — experience. "Having good grades and being a good researcher aren't necessarily the same thing," he said.

"It's one of the reasons I came to the University. There are a lot of good students," he said. It irritates him when talk of teaching leaves out instructing students like Kaspar to become scientists.

"Allan has the tools to get into really top programs," Schook said. "He's quiet around us, but he's very conscientious, very dependable."

And it shows. Kaspar is exasperated with not knowing the details of his project well. He would like to have all the answers today.

But, he said, if he knew it all, then there would be no reason for research.

Claudine Cole, agricultural communications graduate, and staff writer at Drovers Journal *in Shawnee Mission, Kansas*

In Progress

Project to Improve Water Quality in East-Central Illinois

Over the next four years, researchers from several state and federal agencies hope to improve water quality throughout the Little Vermilion River in east-central Illinois by helping farmers to adopt improved agronomic and pest-management practices that reduce soil erosion and agrichemical transport.

The Little Vermilion River watershed is the focus of a recently awarded federal project called the Little Vermilion River Agricultural Nonpoint Source Hydrologic Unit Area. The watershed includes 122,240 acres in parts of Vermilion, Champaign, and Edgar counties. Georgetown Lake, an impoundment on the river, serves as a water resource for the 4,200 inhabitants of Georgetown, south of Danville.

The Illinois EPA has classified the lake as impaired because of inadequate water-storage capacity and poor water quality. These problems have been attributed to siltation and high nitrate concentrations as a direct result of farming practices in the watershed.

Administered by the U.S. Department of Agriculture, the water-quality project involves cooperation among several agencies, including the Agricultural Stabilization and Conservation Service, the Soil Conservation Service, the Illinois EPA, the Illinois Natural History Survey, and the Illinois Cooperative Extension Service and Agricultural Experiment Station.

UI researchers J. Kent Mitchell of the Department of Agricultural Engineering and Allan S. Felsot of the Office of Agricultural Entomology will support the project by monitoring the transport of nitrates and pesticides into the river. They will focus mainly on the contributions of tile drainage to the nitrate loads in the river and lake. As greater areas of the watershed come under improved management practices, the researchers hope to document declines in the loads of agrichemicals leaving the fields.

—Allan S. Felsot

UI Student Wins Prestigious Award

Maxine Cameron, a UI doctoral student in animal sciences, has won a 1991–92 Purina Mills Research Fellowship carrying a $12,500 stipend. The fellowship will support Cameron's research in ruminant nutrition.

Cameron's research, which began this fall, focuses on the nitrogen requirement of microbes in the rumen (a cow's first stomach). With better information about the requirements of these microbes, dairy operators will be able to blend different protein sources to improve a cow's ability to digest feed.

The 27-year-old researcher is one of four agricultural students nationwide to win the fellowship. The competition is fierce, Cameron said. "I've been trying for three years to win one."

A native of Canada, Cameron grew up on a dairy farm north of Calgary, where her family milked 100 Guernseys. She was a member of 4-H for 13 years.

She came to the UI after receiving a bachelor's degree in animal breeding and genetics from the University of Alberta in Edmonton. At UI, she developed a keen interest in ruminant nutrition, the subject of her master's degree and doctoral research at the UI Department of Animal Sciences.

"It's been nice coming into a huge department. This is a very creative atmosphere because you have so many people to bounce ideas off of," she said.

After completing her doctoral degree, Cameron plans to get a research job in industry and eventually run a dairy consulting company.

—NN

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FOREST PRODUCTS

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Forest Products

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 33, Number 4

The Cover

The aesthetic and recreational value of Illinois forests is measured by the millions of citizens who visit each year. Snow creates a lacey covering on the trees at Ten Mile Grove, Ford County, Illinois.

Photo by Robert J. Reber

At a time unlike any in the past, we must envision the future.

— Raymond G. Cragle, AES Director, 1978-1983

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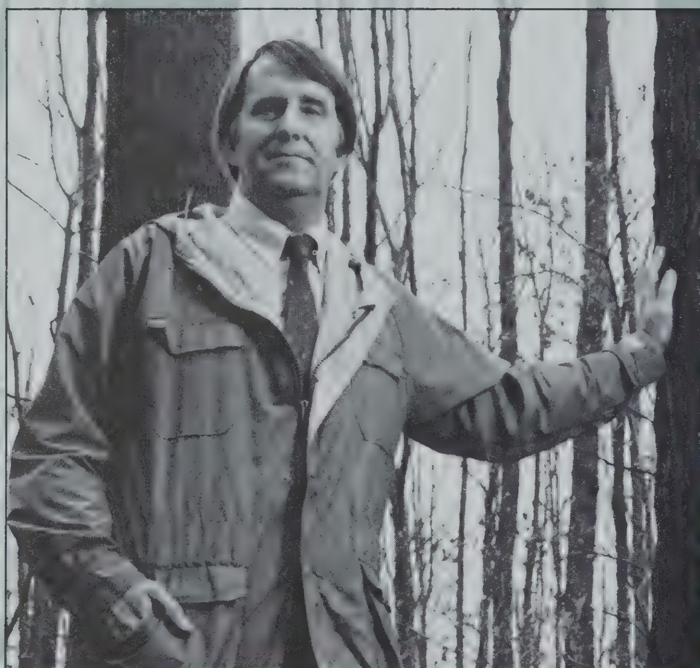


Gary L. Rolfe

When people think about agricultural products from Illinois, they usually think of corn, soybeans, and beef cattle. Wood products and the many other products of our Illinois forests do not normally come to mind. But if you could put a dollar value on all the products our forests provide — wood, recreation, aesthetics, soil protection, and air and water quality, to name a few — the economic value would easily exceed that of the agricultural products we normally associate with Illinois.

Illinois is an interesting state from the forest-products perspective. We are fifth in the country in the use of wood, but rank in the bottom ten states in production. However, the opportunity for a tremendous increase in production that could substantially narrow this gap is well documented. Increased production and harvest would create many new jobs for Illinois citizens and value-added revenue for the state. One of the unique aspects of the forest resource is that management to accomplish economic gains can actually enhance the quality of the forest for a multitude of values that benefit all citizens.

While increased production of wood products is attractive economically, the many other values from our forests are even more important. Consider products such as recreation and aesthetics. Our forests provide recreational opportunities for millions of Illinois citizens. Although the economic value of these recreational visits can be calculated, the intrinsic value to the health and happiness of Illinois citizens is immeasurable.

Soil protection, water quality, and air quality also directly relate to the health and distribution of our forests. In several areas of the state, forest cover has been reduced to the point that soil protection and air and water quality are greatly impacted by alternative land uses. Many organizations have made positive gains by aggressively promoting tree planting and reforestation in these areas over the past few years, but more work must be done.

A critical issue that we must address as we move toward sustainable forestry for Illinois is the need for a comprehensive forest resource education program for Illinois citizens. Some elements already are in place, and we continue to work towards such a program through the Illinois Council on Forestry Development and many related agencies and organizations. This is especially important because Illinois citizens must know more about their forests if they are to make informed decisions about management. Such a program can result in management decisions that strive toward quality and sustainability of forests — Illinois' most valuable resource — while avoiding management decisions overly influenced by narrow-interest groups.

The opportunities for a host of valuable products from Illinois forests are readily apparent, as readers will discover in reading this issue of *Illinois Research*. To achieve these products in a sustainable manner, however, requires good management decisions with public support and understanding. Ultimately, a comprehensive statewide public education program based on scientific knowledge of the forest resource can help achieve this goal.

Gary L. Rolfe, professor, forest ecology and environmental studies, and head, Department of Forestry

Unlimited Potential for Forest Products

Tina M. Prow

There was a time in Illinois when trees were a nuisance, an impediment to settlers carving communities out of wilderness and to landowners envisioning field crops stretching to the horizon. From 1820 to 1920, the 13.8 million-acre forest was reduced to 3 million acres.

The number of wooded acres has gradually increased since then, to about 4.27 million acres today. Much of the increase came after the 1960s, when attitudes toward forests seemed to change, according to Allan Mickelson, chief of the Illinois Division of Forest Resources. Conservation became a watchword; trees became valued assets. He estimated Illinois forest areas have increased by one-quarter million to three-quarter million acres in the past decade, and that all signs point to continued growth.

"We went through a period when all we could see across the state of Illinois were bulldozers pushing out forestland, hedgerows, and fingers of timber," he said. "Landowners were doing lots and lots of land clearing when farm values were rapidly increasing, as were the prices for corn, soybeans, wheat, and other farm grains.

"But a renewed awareness of what forests offer and possibly landowners' concerns about conservation, as well as regulatory compliance related to cropland soil erosion, have meant a lot of highly erodible land is now returning to forestland."

Public Perception

With almost 95 percent of the forestland privately owned, responsibility for managing the state's forests rests largely with about 169,000 citizens. The Illinois Council on Forestry Development, created by the 1983 Illinois Forestry Development Act, has been instrumental in promoting good stewardship through a variety of educational programs, Mickelson said.

The federal and state governments also have helped stimulate interest in forestry through incentive programs. Illinois ranks sixth in the nation in new forest acres planted under the Conservation Reserve Program. Through the Illinois Forestry Development Act, landowners with five or more acres of forestland can take advantage of an 80 percent cost-share program for implementing approved management plans. The Act also guarantees these landowners the lowest possible real-estate assessments.

"The incentives are addressing some of the problems landowners had: high taxes, long-term investments, high front-end costs, and fairly high risk of capital investment over that long period of time," Mickelson said. "As a result of the stewardship activities by the Council and the incentive programs, interest in forestry in the state is at an all-time high."

Still, few landowners are aware of the potential value of the timber on their back-forty, he said.

And the public, in general, has been slow to recognize the environmental quality and recreational opportunities that can be affected when wooded areas are mismanaged, the forester added.

"We have taken our trees for granted far too long. It's only when forestland starts to disappear that we realize we may lose something of importance and great value to us — whether it's the street tree in front of the house or the 40 acres of bottomland that may be subject to going to row-crop agriculture," Mickelson said.

Product Potential

Although Illinois has a relatively small forest acreage compared with other states, forestry potential in terms of commercial value appears to be unlimited, he said. While most states with strong forest industries market pine, Illinois offers higher-value hardwoods. The state's rich, productive soils are especially suited to many of the hardwood species that yield high-quality products. Illinois forests contain nearly 2 billion trees from 261 species, including oak, maple, hickory, ash, walnut, and other softwoods and hardwoods.

"When you look at several hundred dollars per tree for high-quality, fine hardwood, it doesn't take long to find the value of Illinois forestland far exceeds the value of northern or southern pine states, where they may have 20 million acres of forestland," Mickelson said. "It's not uncommon for timber buyers to buy a single tree in Illinois, while in much of the rest of the country, it takes several acres of pine to equal the value of one high-quality red oak or white oak."

Because most wooded areas are privately owned, the timber can be sold easily, with few of the restrictions that hamper sales from state and national forestland. More than 900 licensed,

bonded timber buyers operate in Illinois. The licensing and bonding requirements protect landowners by guaranteeing the contracted price negotiated for their timber.

Despite the interest in Illinois timber, annual timber growth still exceeds timber harvest by enough that Mickelson considers Illinois forests underutilized. Annual timber growth averages 96 million cubic feet, while timber removal averages 68.6 million cubic feet. With better management, forest growth could increase three- or fourfold — and harvest, recreational, aesthetic, and environmental values would increase by as much or more, he said.

"It's a very safe harvest when you're just removing annual growth; every foot cut is literally replaced within that year's time," Mickelson said, adding that harvest improves forest value by opening space for the young, high-quality trees left behind. An indirect benefit of harvest comes through a fee collected from timber sellers. The fee is "recycled" back to the forest through the state's cost-share program for forest management plans and activities of the Illinois Council on Forestry Development.

In addition to having a large pool of timber buyers, Illinois has more sawmills and a larger secondary industry than most states. Sawmills cut lumber from logs, while secondary industries process boards into semifinished or finished products for use in furniture and other manufacturing. Considered together, forest-related industries in Illinois employ about 55,000 people and have an annual payroll averaging $965 million. The industries contribute more than $2 billion to the state's economy through value added by manufacture.

Although all the pieces are in place — timber, sawmills, and secondary industries — the Illinois forest industry still falls short of meeting its full potential. Illinois ranks fifth in the nation in demand for wood, but thirty-second or lower in production of wood. In the face of that demand, however, Illinois forests are underharvested. Added to that, nearly 14 percent of the harvested timber is processed in neighboring states and often imported back into Illinois.

"What we're seeing is that because we're not cutting the full or maximum potential, our sawmills are not producing all they can. The secondary industry, in the quest for materials, is buying wood from out of state," he said. "So, we've got a timber buyer or sawmill buying Illinois wood from a private landowner, sending it to Indiana or North Carolina for drying and semifinishing, and then selling it back to the furniture industry in the Chicago area. When that happens, Illinois loses out on the value-added aspects of forestry."

Efforts are under way to close the gap between sawmills and product industries by establishing more dry kilns and secondary processing facilities in Illinois. And the Illinois Council on Forestry Development is targeting secondary industries for information on the range of high-quality forest resources they can find in their home state.

"Everything looks great in terms of forestry potential in Illinois. We have a high level of interest in forestry by the landowners. Wood is readily available to buyers. We have a large number of buy-

Forestry potential is unlimited in Illinois, where rich, productive soils are especially suited to many of the hardwood species that yield high-quality products, such as this forest of oak and maple.

Photo © David Riecks

The Illinois forest is the setting for a wide variety of recreational activities, such as boating, fishing, and bird watching.

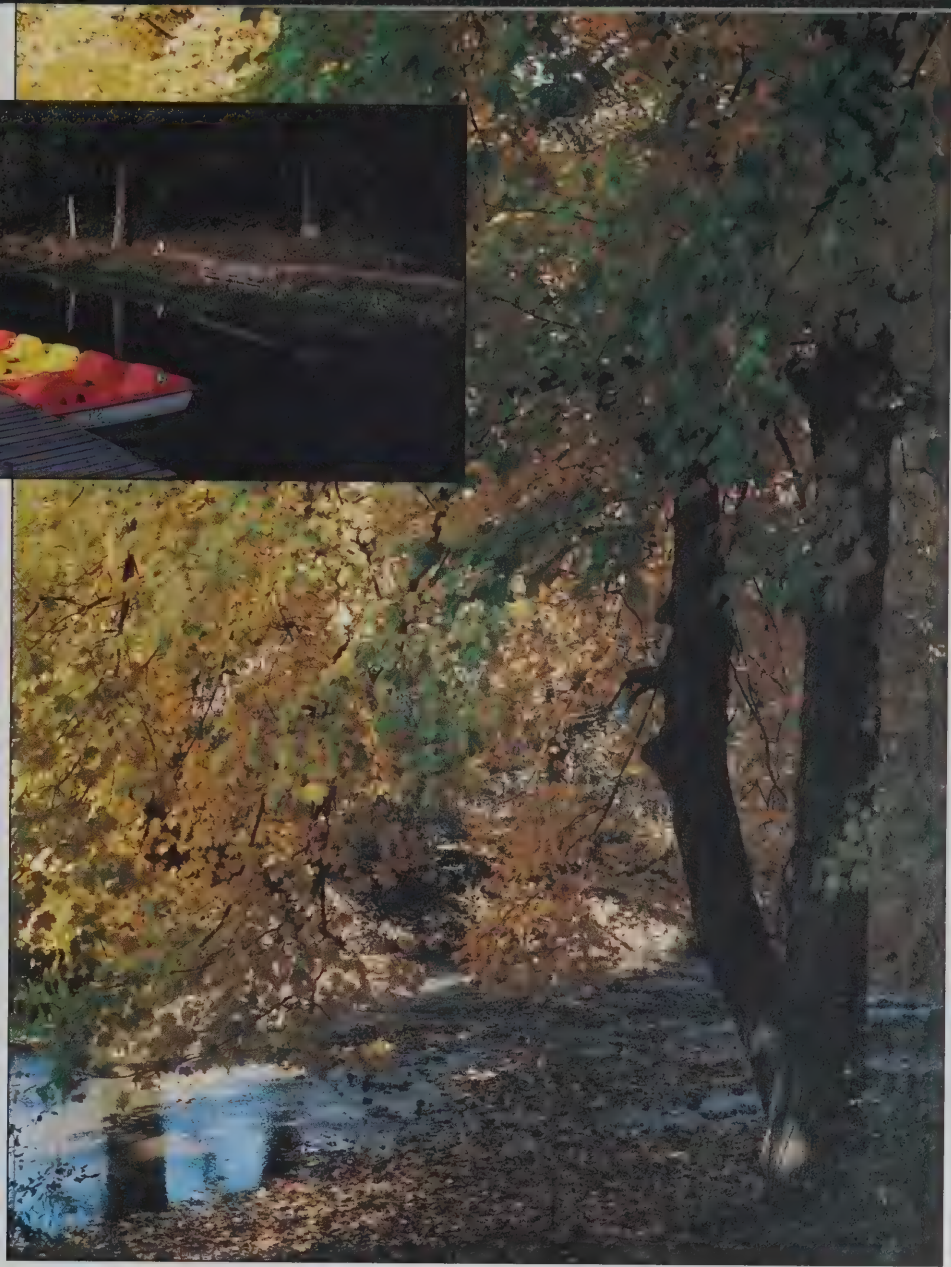


Photo by Robert J. Reber

ers, a fairly well-financed primary industry in sawmills, a growing number of dry kiln operators coming into the state, and a large number of secondary industries. So Illinois is in a position to capture all the value-added benefits received from the products," he said.

The Hidden Potential

But forestry is more than flatboards, Mickelson pointed out. In Illinois, forests also are used for agricultural products of such high-value crops as ginseng, shiitake mushrooms, and Christmas trees. About 2 million cords of firewood are taken from wooded areas each year.

Forest areas also provide a setting for horseback riding, camping, hiking, skiing, off-road vehicle use, hunting, fishing, boating, and bird watching. Time spent on or near forestland in 1987 was equal to an average 19 days per year for each Illinois resident. The fact that urban forestry is a $300 million industry in Illinois is a further testament to the public's desire for trees.

Forest-related recreation is more than fun and aesthetics, however. It meant employment for 150,000 workers in 1985. Recreational services generated $1.8 billion in taxes that year, and personal spending for forest-related recreation totaled $1.2 billion. Added together, the tangible benefits of forests contribute more than $6 billion to the state's economy.

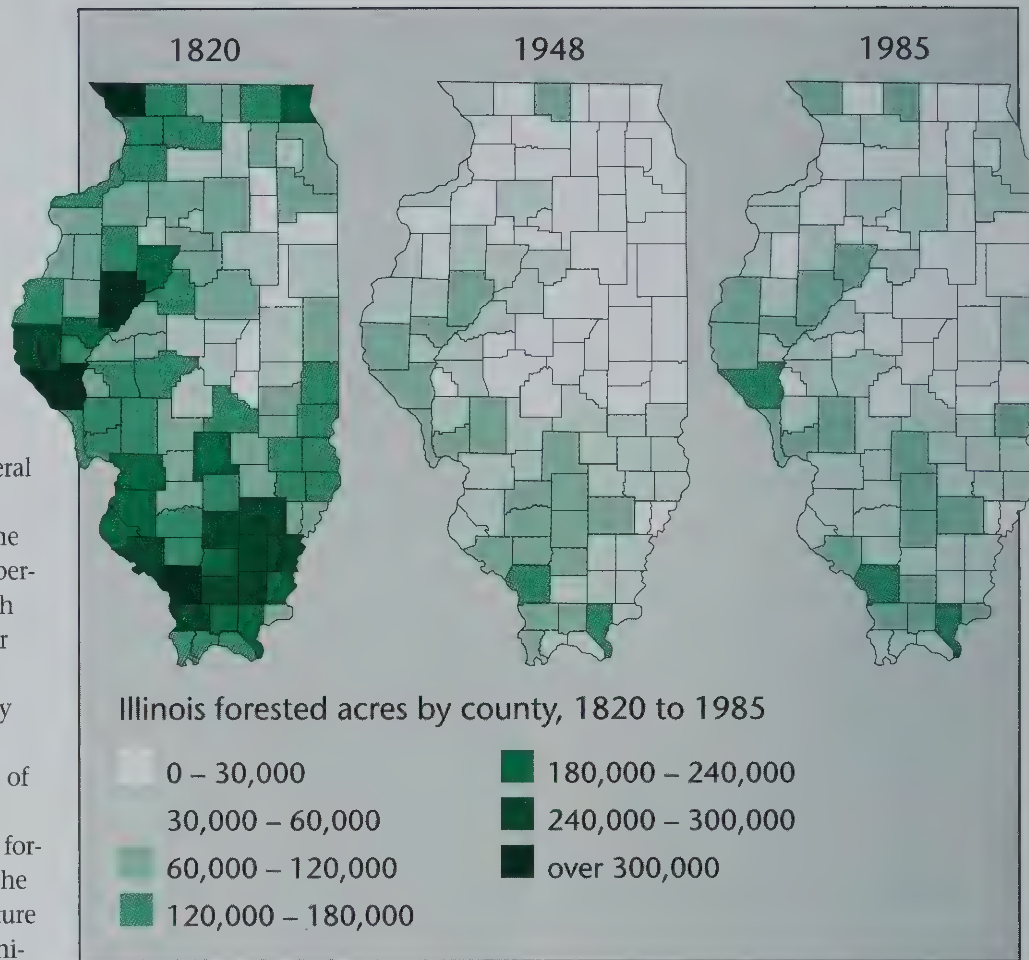
While forests are clearly important economically, the greater benefits from forestry are environmental, Mickelson said. Trees have a vital role in reducing global warming, improving air quality, protecting water quality, and reducing erosion. Used as windbreaks, trees conserve energy for homes, shade livestock, and protect cropland. Many wildlife and plant species are dependent on wooded areas for habitat. Although forests cover only 12 percent of the state, more than 1,500 plant species are associated with forestland; nearly 170 threatened or endangered plant species require forest habitat.

Determining how Illinois forestry potential can be managed for all uses and values — from Christmas tree farms to lumber to wildlife habitat — is a task of the Illinois Council on Forestry Development. The Council has assessed forest-related resources and programs and developed a plan for enhancing and using forest resources. Their goals for Illinois forestry include: retaining existing forests and improving forest management; encouraging landowners to convert 2.5 million acres of marginal cropland to forestland; stimulating the Illinois wood industry to improve and expand its capacity and marketing; promoting community forestry programs; and strengthening and expanding conservation education programs.

Tina M. Prow, science writer, Agricultural Experiment Station

A History of Illinois Forests

Louis R. Iverson



Illinois forests have undergone radical change since the first European settlers came in the early 1800s. According to records of the U.S. General Land Office, which began mapping Illinois' forest, prairie, and water in the early 1800s, Illinois was formerly 38 percent forested (13.8 million acres), with 61 percent prairie and 1 percent water (see maps).

Except for the seven most southerly counties, which were almost entirely forested, and the Grand Prairie region of east-central Illinois, which was only about 16 percent forested, prairie and forest were fairly equally divided across the state. Ecological factors such as moisture regimes, soil types, natural fire, and animal grazing, and cultural factors such as fires set by early settlers, determined the specific distributions.

Today, however, only 31 percent of the forests existing in 1820 remain, and secondary forest or regrowth from cut-over timberland predominate. As of 1985, forestland accounted for only 4.27 million acres (12 percent of the state's land area), whereas prairie essentially did not exist (less than 0.01 percent). Further, only about 11,600 acres of forest remain in a relatively undisturbed condition (that is, old-growth forests, essentially all of which are now designated as high-quality natural areas). And only 11 percent of the entire state has retained its original vegetation type (ranking 49th among states, ahead of Iowa).

Until 1830, forests were the only source of agricultural land in Illinois; land that could not support trees was thought to be of lesser quality. Soon, however, farmers discovered that prairies also made good cropland, and with the advent of the moldboard plow the prairies were converted to crops at an astonishing rate that reached 3.3 percent (nearly 700,000 acres) per year.

More than 300,000 people settled the prairies during the 1830s, and this population created an enormous demand for housing material, fuel, and fence posts. Railways were not yet in place to import lumber, so most of the timber available along the streams rapidly disappeared.

By 1860, a timber industry had begun to flourish. Ninety-two of the state's 102 counties had industries based on wood products by 1870, and forestland had dwindled to 6 million acres. During the 1880s, annual production of lumber exceeded 350 million board feet, more than twice the current level of production, and production continued to increase until 1900, when the resource itself began to decline. By 1923, only 22,000 acres of the original 13.8 million acres of forest had not been logged or otherwise disturbed. Half of those undisturbed forests were subsequently disturbed.

Despite this history of forest exploitation, some aspects of Illinois forestry have recently improved. Overall, the amount of forestland has increased in recent decades. Forest acreage grew by 10 percent between 1962 and 1985, up from 3.87 million acres. The amount of forested land has generally increased since the 1920s, when forest acreage covered an estimated low of 3.02 million acres.

Several state and federal programs now provide incentives to plant trees and to better manage existing forests. These programs are effective and beneficial to the landowner and society in general. For more information, contact your district forester or the Illinois Department of Conservation, Division of Forest Resources, 524 South Second, Springfield, IL 62701, (217)782–2361.

Louis R. Iverson, ecologist, Illinois Natural History Survey and UI Department of Forestry

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Turning Tree Bark into Profit

David J. Williams

Clean-air legislation in the 1960s forced the paper and lumber industry to develop alternative uses for tree bark, a byproduct traditionally disposed of by burning or landfilling. These disposal methods became too costly and environmentally unsound for continued use by the industry.

Researchers in the Department of Horticulture found that the bark of both hardwood and softwood species could be processed and used as landscape mulch or as soil amendment in the production of nursery crops in containers.

Because the forests of Illinois and southern Indiana are dominated by hardwood tree species, bark is the largest byproduct of the lumber and paper industries. Bark quality varies greatly, however, depending on tree species, type of equipment used for debarking, wood content, age of the bark, and how the bark is processed. At the UI Agricultural Experiment Station, research determined that debarking equipment should remove as little wood as possible, and that screens should be used to separate the bark into different grades by particle size.

Mulches

Organic materials have been used to mulch gardens and landscape beds for many years. Mulching-grade bark is produced by using a two-inch screen to remove large unsightly chunks of bark and trash. Because of the weight, shipping bark from the production site to its use site can be costly. Shipping costs can be reduced, however, by screening the fine particles out of the bark. This reduces the weight and makes long-range trucking of the bark more feasible. When a 0.5 inch screen is used to remove the fines, they can then be used as a potting medium.

Hardwood bark mulch is sold in bulk and is available at all landscape contractors and garden centers that carry bulk materials. It is dark brown in color and excellent for reducing weeds and conserving soil moisture. Pine bark is more readily available in bags than in bulk. It is lighter in color than hardwood bark, but also functional and quite decorative.

Potting Media

The presence of a plant growth inhibitor and the bark chemistry of hardwood tree species caused disappointing results in early potting medium studies. However, this inhibitor was eliminated by composting the hardwood bark for ninety days. The carbon/nitrogen ratio of hardwood bark is 200/1; the ideal ratio of a potting medium should be 20/1. This was compensated for by adding six pounds of ammonium nitrate per cubic yard of bark prior to composting. Bark was piled in windrows approximately six feet high for composting. During composting the temperature of bark windrows reached 160° F. When the piles began to cool, they were thoroughly turned and allowed to reheat. This process should be repeated twice to ensure good composting.

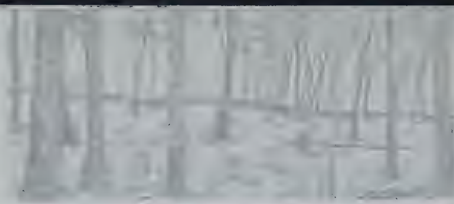
Hardwood bark contains all of the essential nutrients for plant growth, but the levels of nitrogen and phosphorus were low. In addition to the nitrogen added for composting, 2.5 pounds of treble superphosphate were added to supplement the phosphorus content of hardwood bark. The greatest problem encountered in using hardwood bark as a potting medium is that it releases calcium as it decomposes, causing the pH to rise above 7.0. Because most plants prefer a pH between 6.0 and 6.5, this can be a serious problem. This problem was solved by adding two pounds of iron sulfate and two pounds of elemental sulfur to lower the pH to a desirable level. Adding the superphosphate and the iron compounds at the time of composting can eliminate separate mixing operations.

Composted hardwood bark has proved to be an excellent potting medium and is the primary growing medium used in the production of nursery crops in containers.

Bark from softwood tree species such as pine, fir, and spruce can also be used as a mulch for potting medium. Pine bark is the most common type of bark found in the southern and north central states. Its chemistry varies greatly from that of hardwood bark, requiring a different set of recommendations for its use. Pine bark is naturally acidic, which makes it excellent for growing acid-loving plants such as blueberries, azaleas, and rhododendrons. For plants that require a pH of 6.0 to 6.5, it is necessary to add five pounds of dolomitic limestone per cubic yard of bark.

Pine bark contains large amounts of gums and resins that do not decompose as readily as hardwood bark. It has a carbon/nitrogen ratio of 300/1, and research has shown that there is little difference in nitrogen depletion between fresh or aged bark. This means that pine bark does not need to be composted before using it as a potting medium.

David J. Williams, professor, Department of Horticulture



Secondary Wood Industries: Where the Value Is!

John E. Phelps and Dwight R. McCurdy

Wood-processing industries are usually divided into primary and secondary categories. Primary industries produce lumber from logs, and secondary industries use the lumber to manufacture finished or semifinished products. Examples of secondary wood-processing industries are many and include the Illinois firms that manufacture pallets, skids and containers, cabinets, furniture, millwork, moulding, handles, gift items, roof trusses, log homes and other prefabricated structures, treated lumber, and almost anything else that can be made from lumber or pieces of wood cut from unfinished lumber.

There are approximately 2,600 secondary wood-using firms in Illinois, employing over 31,000 full- and part-time employees, according to a survey conducted in 1984 by scientists in the Department of Forestry at Southern Illinois University at Carbondale (SIUC). Industries with over 100 firms each are millwork, kitchen cabinets, miscellaneous wood products, wood partitions and fixtures, and signs and advertising displays. The millwork industry is the largest employer, followed by the miscellaneous wood products and wood partitions and fixtures industries.

Durable, low-maintenance maple countertops combined with oak cabinets produce a functional yet aesthetically pleasing kitchen.

Secondary wood-processing industries are important to the state because of the value-added benefits. The value of the wood increases as it is manufactured into a product; this benefit is passed on to local economies by payments to employees, purchases at local stores, and taxes to the community. Conservative estimates show that for every dollar of log harvested, about two to six dollars come back to the local economy through secondary manufacturing. This range is important because value added is dependent on the amount of further processing of the lumber. For example, there is more value added during the production of furniture than during the production of pallets.

Illinois enjoys a wide variety of secondary wood-using industries, from kitchen cabinets to advertising displays and signs. Data from the 1984 SIUC survey can be used to show the potential use of Illinois wood in secondary wood products; data from the 1987 Census of Manufacturers can be used to describe the total number of establishments or firms, number of employees, payroll, value added by manufacture, cost of materials, and value of shipments for various secondary wood-using industries. The Census was conducted by the U.S. Department of Commerce, Bureau of the Census; another census will be conducted this year. Information is published in the 1987 Census of

Manufacturers, Geographic Area Series Illinois. Statistics for Illinois for the years 1987, 1982, and 1977 are given in Table 1.

Secondary Wood Industries in Illinois

The Census of Manufacturers divides industries into several groups based on Standard Industrial Classification (SIC) codes. Secondary wood industries in Illinois include the following groups:

Millwork, plywood, and structural members group: fabricated wood millwork, wood kitchen cabinets and wood bathroom vanities, and structural wood, either of a laminated wood design or wood trusses.

Wood containers industries: wood pallets and skids firms, and some industries that make shook (box parts) and berry baskets, for example.

Miscellaneous wood products: treated wood, reconstituted wood, and wood products not elsewhere classified. This latter category includes wood handles, wood dishes, wood dowels, wood mauls, and novelty items.

Most of the industry groups are heavily influenced by what is happening in the housing and construction markets. We know that interest rates influence new home construction and the purchase of existing homes. The recession of 1982 is clearly evident in many of the figures except those in the wood containers, pallets and skids, and wood office-furniture industries.

In the past ten years, the millwork, plywood, and structural members industries have shown an increase in the number of employees and value added due to manufacturing, except during the recession years. Wood containers, pallets, and skids industries have shown slight increases over ten years, and those industries that comprise the miscellaneous wood products industries have shown a gradual decrease in numbers of employees with a modest increase in value added.

In 1987, 466 firms produced furniture and fixtures. This industry group includes firms that manufacture furniture and fixtures out of wood and other materials, most commonly metals. Manufacturing establishments in this industry group that use wood include wood household furniture, upholstered household furniture, wood office furniture, public building and related furniture, and wood partitions and fixtures. In general, the number of employees in the furniture and fixtures group has decreased over the last ten years, except in the wood office-furniture industries. Where data are available, trends show an increase in value added due to manufacturing, except in the upholstered household-furniture industries. These decreases in number of employees and increases in value added may reflect general business attitudes in some industries toward leaner organizations.

Another major user of wood and plywood in Illinois is the signs and advertising displays industry. This industry has shown some stability over the last ten years in numbers of employees, but there has been an increase in value added due to manufacturing.

Table 1.
Census of Manufacturers Statistics for Secondary Wood-Using Industries of Illinois: 1987, 1982, 1977

	1987		1982		1977	
Industry group	Number employees	Value added (millions)	Number employees	Value added (millions)	Number employees	Value added (millions)
Millwork, plywood, and structural members	5,300	226	3,200	86.4	5,300	115.4
Wood containers, pallets, and skids	1,000–2,499	(NR)	900	19.2	800	12.7
Misc. wood products	3,600	116.5	4,100	114	5,200	100.1
Wood household furniture	1,400	56.6	1,700	38.9	1,900	31.1
Upholstered household furniture	500–999	(NR)	900	22.8	2,700	47.2
Wood office furniture	250–499	(NR)	500–999	(NR)	150–249	(NR)
Public building and related furniture	500–999	(NR)	800	29.3	1,100	19.7
Wood partitions and fixtures	1,000–2,499	(NR)	2,600	97	2,400	53.8
Signs and advertising displays	5,200	236.2	4,800	157.7	5,100	110.8

Note: NR means that the data were not reported due to low numbers of industries and, consequently, the danger of loss of confidentiality.

Note that wood raw material purchased within Illinois may include wood from trees that is actually grown in other states and shipped to Illinois for sale.

Where the Firms Are Located

When the number of firms is examined on a regional basis, it is apparent that most of the secondary manufacturing firms are located in the Chicago area. For example, 52 percent of the lumber and wood products firms (includes sawmills as well as millwork, kitchen cabinets, and structural members), and 76 percent of the furniture and fixtures firms (both wood- and metal-using firms) are located in the five counties that include Chicago and the surrounding area. Other areas where there are more than ten lumber and wood products firms in secondary industries are Madison County (Granite City), Rock Island County (Quad Cities area), and Winnebago County (Rockford).

Where does the wood come from for these industries? In SIUC's 1984 study, secondary industries were asked if they purchased raw material from within Illinois. Table 2 shows some of the results. Note that wood raw material purchased within Illinois may include wood from trees that is actually grown in other states and shipped to Illinois for sale.

Most likely, cants, lumber, dimension stock, and pallet lumber come from trees grown in Illinois, but this may depend on the location of the firms. Prefinished components could be produced by Illinois firms, but panelboard products such as plywood, particleboard, and veneers or paneling are quite likely imported into Illinois because we have few, if any, firms that manufacture these products.

Panelboard Products

Large amounts of panelboard products are used in secondary industries, except for the pallet industry. A large amount of lumber is also used in these industries, as one would expect. Lumber purchased in Illinois is used within Illinois kitchen cabinet firms but is used less often in the other secondary industries. Only 43 percent of the lumber used in pallets in Illinois pallet-producing firms is purchased from Illinois businesses.

The cited statistics on panelboard products illustrate the potential for establishment of panelboard production firms within Illinois. Recent technological advances have shown that a number of Illinois hardwood tree species can be used to produce these products.

There is also increased potential for the use of Illinois grown species in the millwork, miscellaneous wood products, and wood partitions and fixtures industries.

Another point to make is that although there are numerous secondary wood-using firms in nonmetropolitan areas of Illinois, the majority of them are located in major urban areas. Most likely these firms are located near the markets as opposed to near the resource — something that primary wood production firms do not do. It is also quite likely that the Chicago market is using lumber from adjoining states, not lumber from trees grown in Illinois, although some research is needed to clarify this point. If this is true, there is enormous potential for Illinois wood to be used in Illinois secondary wood products. Through current studies, the Department of Forestry, Southern Illinois University at Carbondale, continues to find some of the answers to these questions.

John E. Phelps, associate professor, and Dwight R. McCurdy, professor and chair, Department of Forestry, Southern Illinois University at Carbondale

Table 2.
Percent of Raw Material Purchased in Illinois by Secondary Industries

Industry	Cants	Prefinished components	Lumber	Dimension stock	Pallet lumber	Plywood	Particle-board	Veneer/paneling
Millwork	NA	100	48	40	NA	74	100	25
Kitchen cabinets	NA	NA	91	100	NA	91	97	NA
Miscellaneous wood products	NA	6	6	42	NA	100	NA	20
Wood partitions and fixtures	NA	NA	62	11	100	70	100	NA
Pallets	26	NA	NA	100	43	NA	NA	NA
Advertising displays and signs	NA	NA	72	100	41	88	NA	NA

Note: NA means data do not apply.

High Potential for Wood Composites

Anton D. Pugel

The two-ply lumber project utilizes low-quality hardwood logs and trees by laminating the backs to a high-quality face.

Two new research projects at the University of Illinois Agricultural Experiment Station concentrate on different ends of the wood-quality spectrum. At the high-quality end is a business plan for a fine hardwood veneer mill and at the low end is a two-ply hardwood lumber mill. Although this research diverges widely on the needed raw material, both projects are intended to add value to Illinois forest resources and promote rural development.

Illinois currently exports 3 million board feet of veneer quality red oak, white oak, and black walnut logs. Most of this material is destined for our neighbor Indiana to help sustain its 16 veneer mills. The cost to build a new veneer mill in Illinois that would generate $5 million of product per year and employ approximately 100 employees is $10 million. If half the investment is borrowed, this operation will generate positive cash flow from year one and have positive net income in approximately nine years. The market for veneer products is divided between domestic and export in a 30 to 70 percent split. The value added through processing is approximately fifty times the cost of the veneer logs. Because the initial investment is high, other scenarios have been developed that employ owner financing and owner participation as the general contractor. Both of these scenarios significantly reduce the payback period. The plan is currently under review by state economic development personnel and investment professionals. The veneer mill business plan has already interested investors in the Far East and Canada, as well as several Illinois entrepreneurs.

The two-ply lumber project was designed to introduce low-quality hardwood logs and trees into traditional high-quality applications such as furniture, moulding, and flooring. Two-ply lumber is generated by laminating a low-quality back to a high-quality face. Research has shown that even low-quality trees produce enough clear lumber to achieve 100 percent utilization of the tree. This product adds value at the rate of five to one. A marketing survey, in which samples were sent to Illinois and Indiana hardwood users, revealed that while this product will not entirely substitute for solid clear lumber, a number of applications are possible and users are willing to try it. It is estimated that the two-ply mill would cost $3 million and generate $500,000 of net income during the first year. This enterprise could be supported at a number of western and southern Illinois locations.

The plans for both of these value-added industries involve many variations that can substantially reduce initial investment and increase net income without affecting the viability of the operations. Alternative scenarios such as air drying, used equipment, and owner participation are currently being investigated to accommodate different investment plans.

These innovative projects represent standard business practices that have been adapted to the unique qualities of Illinois and the forest products industry. They also serve as models for other business opportunities in the wood industry because many of the elements such as raw material supply markets and processing equipment are the same. In this way, forest entrepreneurs can effectively take advantage of sound planning, assistance programs, and the advice of investment professionals.

Anton D. Pugel, visiting assistant professor, Department of Forestry

Medicinal Products from Tree Sources

Anton D. Pugel

Trees are often the source of cures and remedies for various ailments that afflict humanity, a fact sometimes forgotten in this age of synthetics. Nearly all of the medicinally important compounds are derived from the fruit, bark, or leaves of trees.

Many modern drugs, for example, have their origins in natural folk cures that proved to be highly effective. And many chemical compounds can only be synthesized with active biological catalysts. A good current example is the drug taxol, which has shown marked success as a treatment for ovarian cancer. Its only source is the bark of the Pacific yew tree (North America).

The following is a list of some of the medicinal products derived from tree sources:

- One of the major uses for **Brazilian sassafras oil** is the synthesis of the perfumery material heliotropin. A potential but unrealized market for heliotropin is in the synthesis of dopa, a pharmaceutical used for the treatment of degenerative diseases (Latin America).

- Substantial volumes of **eucalyptus oil** are produced in Brazil from the foliage of several species, each of which yields an oil with definitive composition and characteristics for use in cold medicines and lozenges (Latin America).

Slippery elm bark (foreground) can be brewed for a soothing medicinal tea and is also the source for throat lozenges.

- **Cinchona alkaloids** from the bark of Cinchona spp. produce quinine for malaria and quinidine for the treatment of heart arrhythmia (Latin America).

- About twenty different Shorea species carry the **illipe nut**, whose oil is used in Europe for candles and soap. It is also used as a salve and taken internally as a remedy for gum ailments (Southeast Asia).

- **Dipterocarp oleoresins** are used in the treatment of gonorrhea and ulcers (Southeast Asia).

- The **styrax genus** produces an aromatic resin and gum as well as benzoin, which is used in medicine and as incense (Southeast Asia).

- The bark of the **cinnamon tree** is used as a spice and has medical properties. Industrial oils are distilled from its bark and leaves (Southeast Asia).

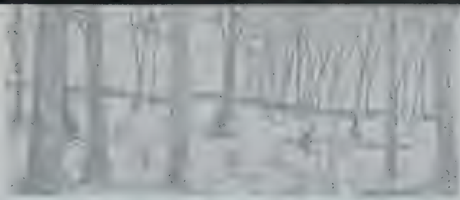
- The **nutmeg or pala seed** from the Myristica fragrans tree is used as a spice, and the oil is used in perfumes and as a digestive aid. It is used industrially in a poison called myristicin (Southeast Asia).

- Toxic heavy-metal ions — especially lead, cadmium, and zinc — in industrial waste waters can be adequately adsorbed by the **bark of several tree species**. Bark substitutes for expensive synthetic ion-exchange resins (North America).

- **Slippery elm inner bark** is the source for slippery elm lozenges (once the source of the extra mucus for baseball's spitball, a legal pitch during the turn of the century) and still popular for sore throats (North America).

Although trees are a valuable pool for new medicinal compounds, they also provide an economic benefit as well. They are avenues that generate immediate and ongoing income from the forest resource in addition to, and sometimes instead of, harvesting trees for wood products.

Anton D. Pugel, visiting assistant professor, Department of Forestry



Forestry's Role in Rural Development and Revitalization

Tina M. Prow

Last year, the Governor's Rural Affairs Council provided $100,000 to kick off an aggressive strategy to develop the international market for western and southern Illinois hardwood products. The funds are supporting a two-pronged approach: studies to determine international market needs, and education of Illinois sawmill owners, secondary processors, and landowners on how to meet those needs.

The effort represents the Council's commitment to the state's forestry potential and is only one of several initiatives being pursued to improve forestry-related opportunities in rural areas, according to Louis DiFonso, executive director.

"Forestry is a rural economic development opportunity, one that creates jobs and produces income in rural areas," said DiFonso. He estimated that Illinois forest-related industries employ about 60,000 people and have an annual average payroll approaching $1 billion.

"Projections indicate that if we properly managed hardwood tracts in the state, we could increase employment and the economic figures associated with the forest industry more than threefold," he added. "Particularly in western and southern Illinois, there is a terrific amount of hardwood capacity that is not being managed to achieve its greatest value."

Governor's Rural Affairs Council

The Governor's Rural Affairs Council, created in 1986 by former Governor Jim Thompson, is charged with a number of responsibilities related to improving the economy and quality of rural life. Council activities focus primarily on three policy areas: rural education, rural health and social services, and rural economic development.

The Council is chaired by Lieutenant Governor Bob Kustra. Participating agencies include the Illinois departments of Agriculture; Commerce; Community Affairs; Conservation, Energy and Natural Resources; Mines and Minerals; and Transportation, as well as the Illinois Development Finance Authority, Illinois Farm Development Authority, Illinois Housing Development, and Illinois Environmental Protection Agency. The Council also includes representatives from Western Illinois University, the University of Illinois, and Southern Illinois University.

With access to that pool of expertise, the Council can act as a "single-stop shopping center" for rural businesses needing technical assistance and for citizens seeking information on managing their wooded land, according to DiFonso.

"People have a variety of different needs and ideas, and they can come to us for help in finding the right people in government to talk to. We can get people together from various agencies, as necessary," DiFonso said. "We do a lot of advocacy work and help people plug into the maze of government."

Forestry Development in Rural Areas

The Council's role as adviser, liaison, and advocate is important considering the makeup of forest ownership and the forest industry, according to DiFonso. Unlike most states, Illinois has no timber company giant, and few landowners own large tracts of wooded land. Instead, the state's industry is made up of about 140 independent sawmills employing about 2,000 people, and 750 wood manufacturers employing about 33,000 people. And almost 95 percent of the forested land is privately owned, much of it in small tracts.

"We've got a lot of small businesses and individuals making money out of it here and there, but it could be better," he said. "In 1984, around 90 percent of the hardwood lumber was imported from other states, even though 90 percent of the hardwoods utilized are hardwood species grown in Illinois.

"Our timber owners are losing out. Our home industry is going out of state for raw materials that they could get cheaper in Illinois because of reduced transportation costs. And it would also produce more revenue for timber owners in the state."

Keeping the economic and employment benefits of the forest industry in Illinois — from harvesting to sawmill to secondary processor — is a value-added approach to rural development, DiFonso said.

Illinois Can Play a Key Role

That concept appeals to Darrell Rich. He and his brothers, Danny and Dennis, own the Rich Lumber Company near Beardstown, a company operating with the philosophy that Illinois can play a key role in filling the wood product needs of the Midwest and the world. They buy most of their raw-grade, center-cut lumber from Illinois sawmills and dry the lumber in on-site kilns. They have a dimension plant for ripping and chopping boards to customer specifications and can glue or machine the boards if customers request further finishing. If the wood is intended for export, they take storage precautions to protect quality.

"Illinois could use more businesses like ours. It's probably not realistic to expect large car companies, for instance, to move into rural Illinois, so crops and timber are what we can work with — and there's a huge potential for forestry," Rich said.

But much of the state's forestry potential is going untapped because of general shortsightedness, he added, pointing out that few landowners recognize wooded areas as "marketable crops" needing management; the highway department passes up millions of dollars in timber sales by not planting trees along roads; and few suburbs have programs for managing trees for market value.

"Illinois is the fifth leading consumer of forest products and only thirty-second in harvesting — it's out of balance," he said. "Unbelievable dollars could be generated by harnessing our potential and bringing in more value-added companies — kitchen cabinet, chair, flooring, stair or furniture manufacturers, to name just a few. Tapping into all of Illinois' forestry potential for a reliable supply would naturally lead to an influx of these businesses."

"Forestry is a rural economic development opportunity, one that creates jobs and produces income in rural areas."

Armed with a belief in the potential of the Illinois forest industry, the Rich Lumber Company developed a plan for renovation and expansion in 1988. They took the plan to the Governor's Rural Affairs Council for guidance in working through the "maze" of government agencies. Using the Council's contacts, the company secured $2 million of financing for renovations that will allow them to further improve the quality of semifinished and finished wood products and meet the growing demand from export customers.

The renovation positioned the company to move to export market sales just as the domestic market dropped. "It happened at the right time," said Rich. "There's no way we could have expanded the business so quickly using normal credit avenues.

"We had 25 percent of our sales in the export market in 1988, and 95 percent in 1991. We have the most modern dimension equipment available, and that has helped us increase yield and product quality. As the quality has increased, we've received more overseas orders."

The family-owned company has undergone dramatic change since it was founded 30 years ago, and the change is paying off. By shifting business goals to export sales, the Rich brothers have captured export sales in excess of $4 million per year. They expect their product quality to continue to improve and attract even more export sales.

The Rich Lumber Company's mounting success with export sales had an immediate impact in their rural community. The company's payroll increased from 35 people, to 80 people, to more than 100 people working two shifts, five days a week — and there is probably enough business for a shift on a sixth day, Rich said.

"Wherever you have expansion, you have job development and additional revenue — and all kinds of new opportunities that come along with them. That's what rural economic development is all about," DiFonso said.

Education Is Key to Rural Development

In addition to working with businesspeople, the Council also lends its support to established programs that could further rural development. With Council backing, the Illinois Association of Resource Conservation and Development Areas hired John Dickson as a marketing specialist, a position expected to have widespread impact. Dickson will help landowners in western and southern Illinois understand the value of their wooded areas and develop a comprehensive management approach. In addition, he will work to establish networks between elements of the Illinois wood industry that may be unaware of each other's resources.

Educating landowners to forestry potential is especially important in Illinois, where the majority of wooded acres are privately owned, DiFonso said.

But forestry potential is more than timber sales, he added. In some areas, it is desirable to manage forests for ecological and aesthetic values, rather than sales value. The Council can put landowners in contact with experts who have information on managing wooded areas for wildlife, windbreaks, watersheds, and other conservation purposes.

"The type of management ought to be a conscious choice that the landowner makes," DiFonso said. "We try to promote forestry from a comprehensive management position. The Council is just as interested in harvesting as it is in planting. We want to ensure that there is a renewable resource for the future by managing for ecological, environmental, and aesthetic purposes, as well as for profitability — these are all important elements of the program."

Tina M. Prow, science writer, Agricultural Experiment Station

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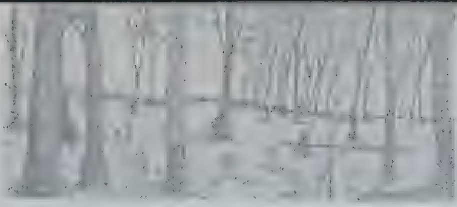

Exporting Illinois Forest Products

Anton D. Pugel

There are many good reasons for exporting Illinois forest products. One of them is the Rich Lumber Company near Beardstown, Illinois, a national leader in exporting hardwood flooring blanks and furniture parts and a good example of progressive thinking and dedication to exporting excellence. Rich Lumber became a successful exporter by hard work, by high-quality standards, and by losing money. While this isn't the textbook ending for successful exporting, it is a common beginning for companies entering the global marketplace.

In the early 1960s, Rich Lumber, owned by brothers Darrell, Danny, and Dennis, was a standard hardwood sawmill. It grew and competed in the domestic lumber market until 1980, when management evaluated its past performance and looked to the future. The future Rich Lumber saw was in value-added secondary processing. The company added dry kilns and a dimension manufacturing plant (a mill that manufactures clear pieces for specific applications in flooring, furniture, and panels), and sold the sawmill business.

As with the sawmill business, Rich concentrated solely on the domestic market until 1987, when a downturn in domestic orders prompted it to export a very small order to Finland. As it turned out, even though its price was 20 percent over the going price, the product was exactly what the customer wanted and was delivered on time. This became the guiding maxim for Rich Lumber — "Where quality is higher than price."

A variety of steps is necessary before products from Rich Lumber Company are ready for export. This shipment of dimension lumber is destined for Germany, one of the nine different countries doing business with the Beardstown company.

An operator uses a laser beam to determine the exact width of the board. The computer then moves the fence to feed the boards into the arbor for the best possible yield.

Rich Lumber averages about five percent more yield than the national average by training its choppers to use the compu-gauge, which determines the best yield when chopping the defects out of the dimension.

Steps to Exporting

Because of the many additional steps needed to complete an export order, it is not surprising that Rich's first experience was a loss. Before an order is even placed, negotiations may take over a year to complete, often the result of exchanging samples and making on-site visits. The product itself may need upgrading to export standards. For example, waney lumber and sapwood are acceptable under standard American grading rules, but most export orders require square edges and all heartwood. And once the order is completed, the shipment must be packaged and labeled to ensure timely delivery through several types of transportation and handling facilities. The processing of export orders is much more involved than domestic sales. Paperwork includes: insurance, freight forwarding, ocean freight requirements, collection, sanitary inspection, currency exchange, and international bankers and lawyers. Rich's loss, however, became an incentive to improvement. Following its initial order, Rich Lumber earned orders for fifty containers per year from the Finland firm. In addition, Rich now exports to ten other countries with export sales reaching 95 percent of total sales for the company. Along with this export success, the company has tripled its employees, upgraded its drying to meet European quality standards, and increased its production capacity by 30 percent in the last year.

Although much of Rich Lumber's success can be traced to desire, vision, and pure luck, its story can be duplicated by other forest industries in Illinois for several reasons. Illinois forests produce high-quality wood, especially in the high-value species such as white oak, red oak, and black walnut. Illinois forests contain the second highest volume of black walnut and the sixth highest volume of white oak in the United States. In addition to these popular species, Illinois enjoys high-quality cottonwood, hackberry, soft maple, hickory, and sycamore. While Illinois does suffer some shipping disadvantage to the East Coast, its excellent transportation infrastructure makes these disadvantages minimal. In addition, higher value products reduce the percentage cost of transportation. Illinois is close to the West Coast where all shipping to the Pacific Rim occurs. Illinois also enjoys a transportation advantage for servicing Western Canada and Mexico.

Resources Aid Exporting Firms

While Rich Lumber Company had to essentially make it on their own in 1987, Illinois has developed several resources to aid ongoing exporting firms and educate new entrants. The Office of the Lieutenant Governor's Rural Affairs Council has been instrumental in spearheading efforts to revitalize rural economies through exporting of wood products (see "Forestry's Role in Rural Development and Revitalization," this issue). The Illinois Hardwood Export Association (IHEA), begun in 1989 through funding by the Council, is an organization specifically designed to increase value for hardwood products. The IHEA helps firms obtain the most value from the raw material, which includes value-added pro-

A Rich Lumber employee sorts panel staves by length, checking them for defects before color matching them for glue-up. From the time that Rich entered the export market in 1987, its plant size and employee numbers have doubled.

Pallets of value-added cut lumber await shipment to Europe after they are stretch wrapped and banded with steel.

cessing, new products, and development of export markets. To this end, the IHEA has sponsored trade missions to Canada, Europe, Mexico, and the Far East and hosted visitors to Illinois from Canada, Mexico, Italy, Japan, Poland, and the Soviet Union. In addition, the IHEA has produced "Hardwoods of Illinois," a brochure that pictorially highlights 12 Illinois species and describes their uses and properties.

From its inception, the IHEA has helped Illinois companies obtain over nine million dollars of export orders. The Rural Affairs Council, in addition to providing seed money for the IHEA, is sponsoring a UI research project, carried out by the Forestry Department, to collect industry statistics and conduct forest-export seminars during the year.

The other agencies involved in promoting exports of Illinois hardwood products are the Department of Conservation, Division of Forest Resources; Department of Agriculture, Bureau of International Marketing; and Department of Commerce and Community Affairs, International Trade Centers.

Exporting has downstream effects of producing business, employee, and community stability through diversified products and markets. It also increases the potential for introducing new products. A case in point for the latter is the growing concern over the use of tropical hardwoods. Illinois species can duplicate the desired properties of tropical woods and may produce demand for cottonwood, sycamore, and hackberry, for example. Yet unlike the tropical species, at the current rates of growth Illinois hardwood volume is expected to double in the next eleven years. Further, under properly managed conditions, Illinois' existing forests are capable of five to seven times more production. Many countries which have banned the import of tropical hardwoods are looking to the United States for their hardwood needs.

While there are many success stories, several impediments still remain to further development of exports from Illinois. First, the small size of many of the 5,000 wood-products firms in Illinois does not allow them to allocate personnel and resources to the requirements of exporting. Second, products which are suitable to the domestic markets may require changes and refinements to meet higher quality standards required abroad for wood products. Third, to be cost competitive with other exporting firms, significant changes may be required in the manufacturing process.

The impediments to greater export success for Illinois companies will be addressed through the research and educational efforts of the many agencies named. For it is rapidly becoming apparent that exporting may not be a luxury for many of the state's forest-based enterprises but instead a necessity for survival in the global economy.

Anton D. Pugel, visiting assistant professor, Department of Forestry

Wood as Fuel

Poo Chow

Surprisingly to most of us, the largest single use of wood in the world is not for paper or lumber, but for the oldest use — fuel. In the less industrialized countries, fuel wood accounts for more than half of the annual harvest of roundwoods.

Today, wood provides 2 to 3 percent of the nation's energy, compared with about 5 percent from hydroelectric power and 7 percent from nuclear sources. The United States consumes only about 8 million tons of fuel wood, or 3 percent of its roundwood production, because fuel wood generally has the lowest value and least demand of any wood product. However, 7 to 10 million tons of wood and bark residue fuels are used every year to generate steam and power at or near U.S. forest product industries.

Caloric Value of Wood Fuel

Dry wood ignites readily and leaves less than 1 percent ash, which has some fertilizer value. Sulfur content of the wood is negligible. Table 1 shows the average fuel analysis of dry hardwood and bark.

The heat value averages about 8,500 British thermal units (Btu) per pound of dense hardwood species such as oak, hard maple, ash, beech, hickory, and birch on an oven-dry basis. By comparison, coal yields about 11,000 Btu per pound and fuel oil, 19,000 Btu. Theoretically, the amount of heat obtained from a ton of oven-dry hardwood and bark equals that from 3 barrels of fuel oil or 0.77 ton of coal. One Btu is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

The greatest drawback to wood as a fuel is its high moisture content when harvested. Wood with a moisture content of 45 percent has a heat value of only 6,000 Btu per pound.

Table 2 shows the effects of wet and air-dry conditions on the weight and heat value of different kinds of wood.

Table 1.
Average Fuel Analysis of Dry Hardwood and Bark by Weight

Constituents	Wood	Bark
	- - - percent - - -	
Hydrogen	6.0	5.5
Carbon	52.0	54.0
Nitrogen	0.1	0.2
Oxygen	41.0	38.0
Sulfur	0.1	0
Ash	0.8	2.3

Industrial Fuel

Of all the wood used for energy in the United States, 80 to 85 percent supplies heat for industrial processes. The largest industrial use of wood residues and spent pulping liquor is to burn them to produce steam, which is then used for drying veneer, lumber, and wood particles or fibers. A steam plant's capacity may range from 10,000 pounds of steam per hour to more than 600,000 pounds at large paper mills.

Today technology is available to build wood-waste fueled plants for generating electric power while meeting governmental pollution control standards.

Table 2.
Average Weights and Heat Value of Wood Per Cord[a] (80 Cubic Feet out of 128 Cubic Feet) and Their Equivalent to That of Coal at Wet and Dry (20 Percent Moisture Content) Conditions

	Weight (pounds)		Heat value (million Btu)		Equivalent in coal per ton[b]	
Wood/kind	Wet	Dry	Wet	Dry	Wet	Dry
Ash	3,840	3,440	16.5	20.0	0.75	0.91
Aspen or cottonwood	3,440	2,160	10.3	12.5	0.47	0.57
Beech	4,320	3,760	17.3	21.8	0.79	0.99
Birch	4,560	3,680	17.3	21.3	0.70	0.97
Douglas fir	3,200	2,400	13.0	18.0	0.59	0.82
Elm	4,320	2,900	14.3	17.2	0.65	0.78
Hickory	5,040	4,240	20.7	24.6	0.94	1.12
Locust, black	5,000	4,200	20.5	24.0	0.93	1.10
Maple, soft	4,000	3,200	15.0	18.6	0.68	0.85
Maple, hard	4,480	3,680	18.4	21.3	0.84	0.85
Oak, red	5,120	3,680	17.9	21.3	0.81	0.97
Oak, white	5,040	3,920	19.2	22.7	0.87	1.04
Pine, white	2,880	2,080	12.1	13.3	0.55	0.60
Pine, southern	4,000	2,600	14.2	20.5	0.64	0.93
Sycamore	4,300	2,800	14.3	17.2	0.65	0.78

[a] One cord is equal to a volume of 4 by 4 by 8 feet, or 128 cubic feet.
[b] Heat value of coal is based on 11,000 Btu per pound.

Fuel for Fireplaces

At present there are about 20 million fireplaces in the United States. Newly designed fireplaces or wood stoves that supplement a heating system could increase the domestic use of fuel wood.

To overcome the bulkiness of wood, bark, and wood residues, such as sawdust and shavings, these materials can be formed into densified briquettes or compressed "logs." These pieces are dry and will burn for a long time, with a 5- or 6-pound log emitting at least 45,500 Btu of heat in a fireplace or wood stove.

Charcoal and By-products

Charcoal, another form of wood fuel, is obtained by distilling roundwood or wood and bark residues under controlled conditions in the absence of air. Compared with the wood used, charcoal has about 50 percent of the volume, 20 to 30 percent of the dry weight, and twice as much heating value. The heat generated is similar to that of high-quality coal.

Charcoal gives out little smoke or odor, so is widely used for broiling and roasting foods in restaurants, trains, and homes in many countries. It is also a good fuel for campers and picnickers, because it does not blacken cooking utensils.

The charcoal industry provides an outlet for low-grade hardwoods that have no other market. About 600,000 tons of charcoal are produced in the United States every year. The distillate remaining after charcoal production can be refined to produce gaseous and liquid fuels in addition to the charcoal.

In addition to direct combustion and distillation, wood can also be converted to energy by gasification, fermentation, and electrification. Some energy is lost in the process of converting wood to charcoal, gas, chemicals (methanol and ethanol), and electricity. It has been estimated that one dry ton of hardwood yields different levels of energy value (Table 3). The efficiency is based on the assumption that 100 percent of the heat content of an oven-dry ton of hardwood yields 17 million Btu. A barrel of oil has a heat content of 5.6 million Btu.

Winter comfort often means a supply of firewood stacked by the home. The largest single use of wood in the world is for fuel, with the United States consuming about 8 million tons of fuel wood (two to three percent of the nation's energy).

Table 3.
Energy Conversion Using Wood

Process		Energy (million Btu)	Efficiency (percent)
1. Distillation (charcoal, gas, chemicals)		15.1	89
2. Gasification:	Gas	14.4	85
	Methanol	6.5	38
3. Fermentation:	Ethanol	5.1	30
4. Electrification (Steam turbine)		4.3	25

Energy Plantations

In remote areas of many developing countries, forests of fast-growing hardwood species are specifically managed as renewable sources of fuel for homes and industry. The drawback to such energy plantations in the United States is the enormous land requirements for any significant addition to our energy supplies. Fueling even 1 percent of this country's electrical generating capacity would require 2 to 5 million acres of fuelwood forest. However, our existing forests can be managed more efficiently to supplement our fuel supply.

It has been estimated that about 23 million dry tons per year of forest logging residues and rotten and salvable dead trees of hardwood species in eastern forests could be used for fuel if conditions and technology existed for their economic harvests.

Poo Chow, professor, Department of Forestry

Illinois Timber Harvests in 1990

Dwight R. McCurdy and John E. Phelps

Controversy surrounding the harvesting of trees in the United States and more specifically within the Shawnee National Forest in southern Illinois prompted a study to determine the amount of timber cutting in Illinois in 1990. Researchers in the Department of Forestry, Southern Illinois University at Carbondale, found that less than 5 percent of the total volume of timber harvested was from the Shawnee National Forest, the largest publicly owned parcel in Illinois.

Firms licensed to purchase timber in Illinois in 1990 totaled 516; the number of buyers has steadily increased in the past fifteen years. The total volume of standing timber (stumpage) purchased in 1990 was approximately 190 million board feet; this figure also has steadily increased in the past fifteen years.

Nearly all (96 percent) of the timber purchased was from private versus public lands (county, state, and federal). Because not all the standing timber purchased in one year is actually harvested that same year, data on the amount of harvesting (or logging) that was done during 1990 is of importance. It is estimated that approximately 194 million board feet of standing timber were actually logged during 1990. This timber was harvested from 86 thousand acres. On most acres, only a portion of the trees was removed, versus clear-cutting all the trees. For example, approximately 2,800 board feet were harvested on average per acre.

Significant Findings

Comparing this data with the extent of forest resources in Illinois, the following findings are significant:

1. The total volume of standing timber in Illinois is 17,495 million board feet. This growing stock volume has a net annual growth of sawtimber (commercial size trees) of 437 million board feet. Thus, only 1 percent of the total volume and 43 percent of the net annual sawtimber growth were harvested;
2. The total acres of timberlands in Illinois are slightly greater than 4 million acres. Thus, only 2 percent of the timberlands were actually harvested;
3. The average volume of timber was 4,340 board feet per acre. With an average harvest of 2,800 board feet, the harvests removed only 65 percent of the volume, on average, per acre where logging occurred; and
4. Specifically, the Shawnee National Forest has 226,000 acres of commercially available timberlands, containing 1,020 million board feet of timber (growing stock). This timber has a net annual growth of sawtimber of 19.25 million board feet. In 1990, 8.7 million board feet of sawtimber were harvested on approximately 1,300 acres. Thus, only 8/10 of 1 percent of the growing stock volume, 45 percent of the net annual sawtimber growth, and 6/10 of 1 percent of the commercial timberland were harvested.

These data indicate that we are currently "saving" much of Illinois' timber. For example, from 1965 to 1985, total net volume of growing stock (timber) has increased by 40 percent. These timber "savings" are becoming one of the state's greatest resource assets that can be used for future economic development. For example, Illinois currently ranks fifth in the United States in the consumption of wood in the production of finished products, but only 32nd in lumber production.

Dwight R. McCurdy, professor and chair, and John E. Phelps, associate professor, Department of Forestry, Southern Illinois University at Carbondale

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PHOTO BY ROBERT J. REBER

Select-cut timber is removed from Illinois forestland and prepared for transport.

Managing Illinois Hardwood Forests

Jeffrey O. Dawson and Theodore W. Curtin

The first Europeans to encounter Illinois found a complex mosaic of deciduous hardwood forests, oak savannas, and tall-grass prairie. The forests varied in composition, reflecting differences in the adaptabilities of the many tree species to Illinois' varied climatic and other environmental influences.

Large, fire-resistant bur oaks occurred in parklike, open groves on the prairies. Shade-tolerant sugar maple and basswood forests occupied deep coves and other areas protected from naturally occurring fires. Riverine forests contained silver maples, willows, green ash, sycamores, cottonwoods, and pin oaks — species that could tolerate flooding.

In deep southern Illinois were cypress and tupelo swamps and a scattering of shortleaf pine in the hardwood forests. Cucumber magnolias bloomed in the far southern tip of the state. In northern Illinois occurred outliers of the northern forests, including eastern white pine, paper birch, and tamarack bogs. But the most common and extensive were forests dominated by upland oak and hickory, forests that included many of Illinois' most valuable timber species: northern red oak, white oak, white ash, black walnut, and black cherry.

These forests were born of disturbance, primarily from fire. Native Americans were probably the first forest and rangeland managers in Illinois, employing fire to aid in hunting game.

The earliest European settlers in Illinois came from regions of deciduous forest to the east and chose familiar forested tracts along rivers to clear and farm. The forest provided building materials for cabins, wood for implements and utensils, and firewood. Prairie incapable of supporting trees had sod impenetrable by early plows and was thought to have little agricultural potential.

Effective management of our complex hardwood forest, rather than exploitation and neglect, is a priority in Illinois. Forestry specialists have access to a variety of resources that include aerial photographs such as the one studied here.

Both Native Americans and European settlers recognized the useful properties of different tree species. Rot-resistant timbers were used for lodgepoles, prehistoric Kaskaskia's "woodhenge" solar observatory (located on the Mississippi River floodplain across from St. Louis), and fences. The strong, resilient ashes and hickories were used for ax handles and agricultural implements. These resources were exploited with little regard for future forests.

America's forests seemed to be an inexhaustible resource to pioneers. Illinois forest cover declined from approximately 40 percent to less than 10 percent of the state's land area since the early nineteenth century. The oaks, hickories, and biologically similar tree species responded to clearing and massive cutting for railroad ties during the last century by reclaiming any land not intensively used for agriculture, housing, and industry.

How Maples and Basswood Are Replacing Oaks and Hickories

Long-term research conducted by the Department of Forestry at Brownfield Woods and other University of Illinois natural areas reflects a recent, widespread trend in Illinois forests: the succession of sugar maple and basswood to become the dominant vegetation in many oak and hickory forests. Maple and basswood also replaced elms killed by the epidemic of Dutch elm disease in many forest stands. A similar trend is occurring in Indiana, where fire was less common in presettlement forests of beech and maple than was the case in Illinois. Indiana's climax forests of shade-tolerant beech and maple gave way to forests with oak as a major component following the disturbances associated with European settlement. Today, where disturbance by cutting and burning has been eliminated in Indiana, beech and maple are again becoming dominant.

Periodic disturbance seems to have been a major factor influencing the presettlement forest landscape. In prairies maintained by fire and on abandoned agricultural land, seeds of oaks, hickories, and walnut are planted by squirrels and, because of their greater weight, are more likely than lighter seeds to fall through turf, contact soil, and germinate. The open conditions of woodlands decimated by fire or logging allow the regeneration of oaks and other tree species with intermediate or low shade tolerance, which is not possible in forests with closed canopies. Many of today's old upland oak forests have resulted from the activities of rail splitters such as the young Abraham Lincoln. Elimination of these periodic disturbances seems to be causing widespread change in the state's forest composition.

The change in forest composition is of considerable consequence to Illinois inhabitants. Red oak, white oak, and black walnut currently have the highest economic value because of the beauty and utility of their woods. Oak and walnut also produce large seeds consumed by native wildlife, including squirrels, white-tailed deer, and turkey.

Extensive efforts to preserve the state's aesthetically appealing native vegetation have brought Illinois to the forefront nationally in terms of prairie restoration and natural-areas management. And maintaining oak as a major forest component has become a focus of forestry research in not only Illinois but also the eastern United States.

Managing Oak Forests

So what can be done? Clear-cutting is not the answer because in many of Illinois' upland forests dominated by oak and hickory, the established understory tree seedlings and saplings consist of only shade-tolerant species such as maples.

The Growing Nursery Industry

Randy L. Vogel
and Anton G. Endress

It is no secret that Illinois, a world leader in agriculture, is best known for its production of corn, soybeans, beef, and pork. People traveling through the state are often surprised at the vast number of large-scale farm operations they see. What they don't often see, however, are the more than 35,000 acres dedicated to the production of nursery stock and the additional 9 million square feet of production in covered structures such as greenhouses.

Nursery stock production, less well known in the state than other commodities, is growing in importance. Landscapers, garden centers, and growers contribute an estimated $865 million to the state economy and provide 25,000 jobs with a payroll in excess of $190 million.

Trees in Demand

These figures were determined in a 1989 survey conducted by the Illinois Agricultural Statistics Service and funded by the Illinois Nurserymen's Association (INA) and the Department of Agriculture Division of Marketing. The nursery industry supplies the trees, shrubs, and flowers used in public and private beautification projects. The number of such projects is increasing. For example, renewed public interest in the environment has created a demand for more tree plantings by local, state, and federal agencies.

Most Illinois growers specialize in finished stock ready for transplanting. Trees, shrubs, and other nursery products are produced both in the field and in containers. Bedding plants and similar products are produced in greenhouses and other covered structures. For a variety of reasons, production of seedlings and other bare root stock has not developed to any great extent in Illinois. The market for these products is served by government and private nurseries outside Illinois.

Garden centers are found all across the state and vary from small "Mom and Pop" operations to multimillion dollar firms offering a wide range of products and services. Landscape firms are well established throughout the state, and some of the largest companies of this type in the U.S. are located in the metropolitan areas of Illinois. However, most firms are family owned and operated. In fact, several production nurseries in Illinois have been in the same family for over 100 years.

Nursery Operators in Illinois

The Illinois Nurserymen's Association itself is an old organization, tracing its history back to December 1915, when several nursery operators attending a meeting of the Illinois Horticultural Society decided to form a state nursery association. Interest and participation led to formal incorporation. Miles Bryant became the

Clear-cutting these stands would only accelerate succession to climax forests of shade-tolerant trees.

Recent research in the Department of Forestry conducted in cooperation with the privately owned Sinnissippi Forest in Ogle County suggests a silvicultural method that may help to perpetuate the presettlement oak and hickory forests. It is a shelterwood process by which trees are cut one or more times to open the forest canopy about 50 percent, allowing the establishment over a period of from seven to thirty years of intermediate shade-tolerant species such as white and red oak. The cuttings are ideally a combination of commercial harvest of some of the valuable dominant trees and improvement cuttings in which diseased trees and seed trees of potentially inferior genetic quality are initially removed.

A seven-year establishment period precludes the decline in wood quality associated with epicormic branches that form on the stems of trees suddenly exposed to sunlight. This is because only the narrow outer wood formed during the prior seven years, which is commonly discarded in the milling process, is affected by epicormic branching.

Once large numbers of seedlings and saplings of the desired oak and other species are established, the overstory is removed. Oaks are prolific sprouters. When the overstory is removed by logging, the stems of oak seedlings broken in the process produce single-stemmed sprouts that, fueled by carbohydrate reserves in their large tap roots, shoot up above the vegetative competition in the suddenly opened site.

These biological responses to management are the same responses that may have perpetuated species such as oak after fires or disturbances associated with past timber harvesting and pasture clearing. A variety of other silvicultural methods, including planting, controlled burning, and selective use of herbicides, are also appropriate for maintaining upland hardwood forests of desired structure and composition.

Only in the past 60 to 75 years have scientific methods for controlling the structure and composition of complex eastern hardwood forests begun to be developed. Most of this work has been done since World War II. These forests are more similar to tropical forests than to temperate and boreal conifer forests in their complexity and consequent management difficulty.

If we are to continue to enjoy the fine hardwoods, distinctive wildlife, clean water, recreational opportunities, and aesthetic qualities of native oak and hickory forests, effective management rather than exploitation and benign neglect will have to be implemented.

Jeffrey O. Dawson, professor, and Theodore W. Curtin, assistant professor, Department of Forestry

association's secretary in 1931, establishing the first INA office at his Princeton nursery. His tenure saw the creation of a newsletter and an expanded yearbook, and the growth of the annual convention into a convention/exhibit that was the foundation for the current Mid-American Horticultural Trade Show (Mid-Am) held each January in Chicago.

INA is a leader in representing the interests of the industry and providing overall support and assistance to its members through services such as insurance programs, educational opportunities, professional certification, and funding for research and scholarships. It publishes "Growing Trends," a monthly magazine that features timely industry news and management-related articles.

One of INA's strongest activities is its legislative program — it is the only green industry organization with an active lobbying program in Springfield, where the industry's interests are represented at the state capitol by the executive director, with the support and assistance of a lobbying firm. INA is headquartered in Springfield, where further information on the association and its activities can be obtained: INA, 1717 South Fifth, Springfield, IL 62703, (217)525-6222.

Randy L. Vogel, executive director, Illinois Nurserymen's Association, and Anton G. Endress, professor and head, Department of Horticulture

More than 35,000 acres in Illinois are dedicated to the production of nursery stock. An additional 9 million square feet of production is carried out in covered structures such as greenhouses.

Christmas Tree Growers Making the Cut

Stephanie Brown

Christmas tree production has become a popular alternative enterprise on thousands of acres of marginal cropland in Illinois. Although the state is not recognized as a major Christmas tree producer, it has potential for long-term growth in the industry. The key to such growth is aggressive marketing in the face of a current nationwide oversupply of natural trees, complicated by some stiff competition with the artificial-tree industry.

More than 500 growers raise and harvest about 500,000 Christmas trees each year in Illinois. Their farms, ranging in size from 1 acre to more than 100 acres, are located throughout the state. Most people who grow Christmas trees in Illinois do so on a part-time basis to supplement a primary occupation or retirement income. Others have chosen the enterprise as a way to diversify their farming operation. In either case, growers find themselves spending their evenings, weekends, holidays, and vacations tending to the cultural practices and marketing techniques necessary for a successful operation.

Despite the labor-intensive nature of the enterprise, the number of Christmas tree farms in Illinois is on the rise. In fact, the state of the Christmas tree industry in Illinois compares favorably with the current expansion of the vegetable industry. More and more people are recognizing that the growing and marketing conditions in Illinois surpass those in other states that are well known for Christmas tree production.

Illinois offers many advantages in terms of growing and harvesting. The soil types and annual rainfall levels are excellent in most areas. Sites for Christmas tree farms are readily available on sloping land that is highly erodible and only marginally suited for field-crop production. Weather patterns are another major advantage. Illinois winters are mild in comparison to the northern states, where tree harvesting must begin long before the Christmas holiday. Less inhibited by harsh winters, Illinois growers are able to supply freshly cut trees that are shipped to market over shorter distances than competitors' trees from the north or west. The only problem is that many local consumers are not aware that Illinois trees are the fresher product.

Consequently, the single most important challenge to be considered by a potential grower is the identification of a market for the trees. Because Christmas trees require six to twelve years to reach a marketable size, growers must locate buyers well in advance of harvest — or risk not being able to sell the trees when they reach maturity. Trees are sold in quantities on a wholesale basis, individually on a retail basis, or off the stump on a "choose-and-cut" basis. The market conditions and trends vary for each method of sale.

The wholesale market is suffering from a surplus of trees. Wholesale growers are finding it more difficult than ever to locate buyers for their product. In Illinois, the problem is complicated by trees from out of state that are trucked in mass quantities to flood metropolitan areas. Studies have shown that nine out of ten trees sold in the Chicago area

Christmas tree production is a labor-intensive enterprise. The traditional planting method involves tamping the soil down after hand planting.

come from other states. Illinois growers are fighting the common misconception that the best product comes from Michigan and Wisconsin, states well known for their Christmas trees.

On the other hand, the trend toward choose-and-cut farms continues to improve in many localities as the baby-boom generation seeks the traditional family experience of cutting their own tree in a farm setting. In most situations, the location of the farm correlates with market demand. Some areas of the state, however, are saturated with Christmas tree farms that must compete for a limited number of customers. Choose-and-cut growers are therefore advised to conduct trade area analyses, similar to the technique used by pick-your-own strawberry farms, before establishing or expanding their farms.

In the face of increasing competition, growers are developing new marketing strategies, such as the sale of wreaths and decorations, hot apple cider, or even sleigh rides to attract holiday customers. Many tree farms and retail lots advertise and use direct-mail campaigns to attract return customers. At the national level, the real-tree industry conducts marketing and publicity campaigns to compete for the market share dominated by artificial-tree retailers. Many states are conducting consumer education programs about the benefits of buying natural trees. Illinois takes it one step further by promoting fresh, *locally grown* trees through marketing and publicity programs.

As Christmas tree growers learn improved marketing techniques and gain experience in growing higher quality trees, they are closely guarding their customer base and attempting to gain the edge over their competition. Illinois growers are determined to make the cut.

Stephanie Brown, executive director, Illinois Christmas Tree Association, and director of the UI Forest Resource Center in southern Illinois

Suggested Reading

Further information on the history of Illinois forests, benefits Illinois forests provide its citizens, and other related forestry topics outlined in this issue can be found in several detailed documents:

- *Forests of Illinois*, Special Publication 11, a 24-page color brochure available free

- *Forest Resources of Illinois: An Atlas and Analysis of Spatial and Temporal Trends*, a 181-page color book detailing the Illinois forest resource, available for $4

- *Forests of Illinois, 1820–1980*, a large wall map available free

- *Firewood for Fireplaces*, information about using wood in fireplaces efficiently, Leaflet No. 1, Department of Forestry.

The above publications are available from the Illinois Natural History Survey, 607 E. Peabody, Champaign, IL 61820, (217)244-2115; or from the UI Department of Forestry, 110 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801.

- The Illinois Christmas Tree Association publishes a buyers' guide listing choose-and-cut farms, retail outlets, and wholesale suppliers. Contact ICTA, R.R. 1, Box 255, Simpson, IL 62985.

Statistics on forest resources and harvesting activity in Illinois are available in the following references:

- *Illinois Forest Statistics, 1985*. U.S.D.A. Resource Bulletin NC-103, Washington, D.C., 100 p.

- *A Comparison of Illinois Timber Buyers, 1976, 1982, 1984, and 1990*. Department of Forestry Publication, Southern Illinois University, Carbondale, IL. 16 p.

Information on stewardship is available in *A Landowner's Guide to Woodland Stewardship*, developed by the Illinois Forest Resource Center. Cost for the guide and three-ring binder is $10. Contact IFRC, R.R.1, Box 255, Simpson, IL 62985.

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Illinois Research

Spring 1992

Focus on Corn

Illinois Research

Agricultural Experiment Station
Spring/Summer 1992

Focus on Corn

Which kernel will survive the journey to Japan?

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 34, Numbers 1/2

The Cover

Stress cracks, as illustrated in the top kernel, lead to kernel breakage during shipment, lowering the value of the corn and diminishing its suitability for storage and processing. Grain quality factors such as this are of great concern to major corn importers like Japan. See "Illinois and the World Corn Market," page 3.

Illinois Research

Spring/Summer 1992
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Focus on Corn

Directions

Kernels of Wisdom


Gary H. Heichel

The *science* of corn culture, improvement, marketing, and utilization has a long and rich history at the University of Illinois. Corn as a *business* in this state has a history equally venerable. This issue of *Illinois Research* is dedicated to updating the science and business of corn in Illinois, a remarkable symbiosis of activities for nearly a century.

Let's reflect on the history of the science, which began in this vicinity 104 years ago. George Morrow began crossbreeding experiments at the Illinois Agricultural Experiment Station in 1888. In 1895 the Board of Trustees, pressed by then Dean Eugene Davenport, adopted a resolution that "Indian corn and its relations from every conceivable point of view ought to be considered the foremost subject for experimentation at this Station."

Little did the trustees imagine that "every conceivable point of view" would evolve a century later into the subjects covered by our authors: corn adaptation and nutrition; corn in international commerce; corn as feed, fuel, and feedstock; corn genetics and quality; corn as a specialty commodity; corn as a premier scientific organism; producer-funded corn research.

The history of corn as a specialty commodity merits a closer look because it is a case study in value added to a state by the "spinoffs" and direct benefits of sustained public support of research and exemplary of future outcomes sought by the Illinois Corn Marketing Board.

To carry out his mission, Dean Davenport hired Perry Holden, who became first head of the Department of Agronomy in 1899; Archibald Shamel, instructor in farm crops and manager of the Experiment Station; Edward East, assistant chemist for the Experiment Station and recipient of the first doctoral degree in agronomy from UI in 1907; and H.H. Love, also an assistant chemist. The latter three assisted Cyril G. Hopkins, Station chemist and second head of the Department of Agronomy, who initiated in 1896 the now-classic selection experiments on high- and low-oil and high- and low-protein corn.

Hopkins married the science and the business of corn in 1901 when he arranged for area farmers, among them Eugene Duncan Funk, to participate in the selection experiments for oil and protein content. Funk was a likely candidate for such a venture. He had tried corn breeding as early as 1892. This is "on-farm" and "participatory" research in modern terms, but as a "spinoff" it stimulated the development of an Illinois seed industry that now numbers about 30 plant-breeding firms, 200 professional plant breeders, and $300 million of annual gross sales within the state.

In 1989, 103 years after the idea of creating high-oil corn germinated at the College of Agriculture, the university licensed high-oil corn germplasm to transnational private industry. In his interview with science writer Tina Prow, John Goss of Du Pont's agricultural biotechnology group reports on the prospects for successful commercialization of this idea after a 6- to 7-year development effort.

Stabilization of world population is predicted by 2050, but until then global production of corn must increase by 250 to 300 percent to meet human needs for plant and animal food. As industrialized countries seek sustainable societies and fuel sources, an increased reliance on corn as a renewable natural resource is likely. Illinois and its citizens, the "Buckle on the Corn Belt" and world source of intellectual capital on the science and business of corn, are uniquely positioned to contribute to the betterment of humankind in the twenty-first century.

— Gary H. Heichel, professor and head, Department of Agronomy

Illinois and the World Corn Market

Darrel L. Good and Lowell D. Hill

The world relies on grain for much of its food, feed, and industrial products. Corn (*Zea mays*) occupies a prominent position among the grains, with production totaling a record 478.4 million tons in 1991 — 28 percent of world grain production. Although this was only about 10 percent larger than the crop of a decade earlier, it outsized the crop of twenty years ago by nearly 60 percent.

Much of the corn grown in Illinois travels by barge down the Illinois River to the Mississippi, then on to New Orleans, where it is loaded in oceangoing vessels.

Who Grows It, Where It Goes

The world's major corn producers include the United States, China, and Brazil. They are followed by Mexico, France, Yugoslavia, and the former Soviet Union (Figure 1).

The United States, the world's top corn producer, accounted for about 40 percent of the world total in 1991, down

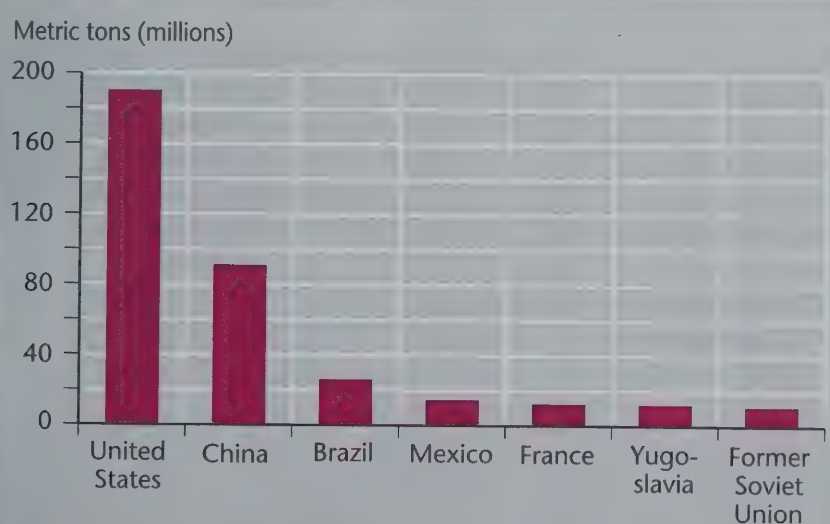


Figure 1. World corn production, 1991.

Note: World production totaled 478 million metric tons.

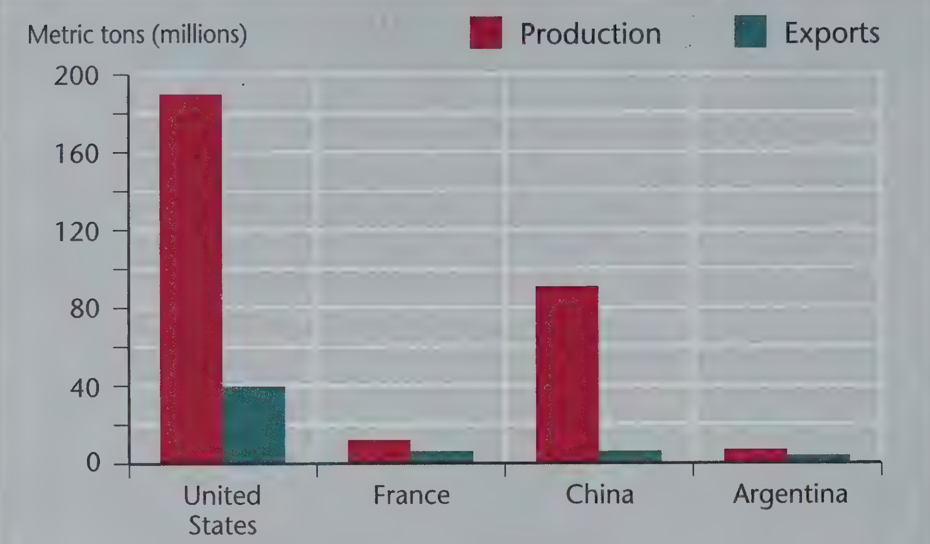


Figure 2. Corn production and exports for selected countries, 1991.

from 48 percent ten years earlier. China, the second largest corn-producing nation, harvested 91 million tons in 1991 — about half the size of the U.S. crop. The three largest producers — the United States, China, and Brazil — accounted for 64 percent of the 1991 crop. Brazil is also a large consumer of corn, with virtually no exports.

Domestic consumption changes the relative ranking of countries in terms of export volume (Figure 2). The four largest exporters in 1991 were the United States, France, China, and Argentina (Figure 3). Argentina's position in this array has declined as farmers have shifted from corn to soybeans in response to economic opportunities.

World corn trade grew dramatically during the 1970s, expanding from 32.2 million tons in 1970–71 to a record 85.3 million tons in 1980–81. The U.S. share of corn exports grew from less than 40 percent to more than 70 percent during that period. In absolute terms, U.S. exports increased from 13 million tons to 61 million tons.

During the next five years, the trend in world corn trade reversed, and total trade volume declined by 27 percent from 1980–81 through 1985–86. The U.S. share dropped to only 50 percent. This decline reflected increased corn production in both importing and exporting countries in response to higher world prices.

World corn trade has recovered somewhat during the past five years but remains well below the levels of the early 1980s. The United States is still the largest exporter of corn, accounting for 65 percent of the world total in 1991. China has traditionally been a minor player in world exports (200,000 to 300,000 tons), but in 1984 its production increased dramatically and exports surpassed 6 million tons in each of the past two years.

Many different economic factors have helped reduce the U.S. export market share — among them, exchange rates and high support prices of the 1970s. Agricultural and trade policies of other countries have also influenced world trade. High prices, artificially maintained by the European Community, have enabled French farmers to increase corn production enough to shift their country from a net importer to a net exporter in the mid-1980s.

U.S. Production

U.S. corn production peaked at 225.5 million tons in 1985. That year, a record 75.2 million acres were harvested for grain, and the average yield was a near-record 118 bushels per acre. By 1991 annual production had dropped to 190 million tons. The annual farm value of the U.S. corn crop has ranged from $12.5 billion to $22 billion over the past ten years.

Typically, Illinois is second only to Iowa as the largest corn-producing state. Illinois producers harvested 11.1 million acres of corn for grain in 1991, producing a crop of 30 million tons. The state accounted for 16 percent of the national corn crop. In recent history, the state's share of the crop has ranged from a low of 14 percent in 1988 to a high of 18 percent in 1982.

But Illinois is unsurpassed in terms of exports, partly because of its access to low-cost transportation on inland waterways. A recent survey revealed that Illinois shippers originated 30 percent of the total volume of corn exported from the United States. In contrast, Iowa shipped only 10 percent of the total.

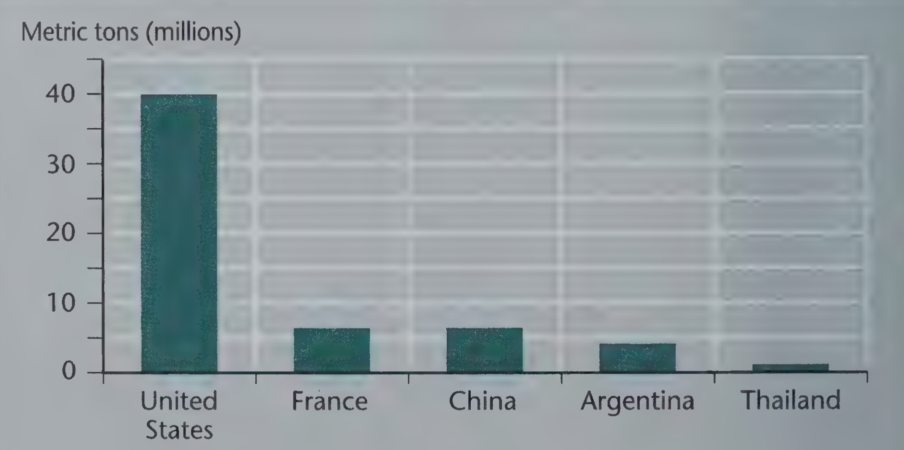


Figure 3. World corn exports, 1991.

Note: World exports totaled 62 million metric tons.

How It Is Used

Two-thirds of the worldwide corn supply is consumed by animals. The relatively slow rate of growth in world corn consumption during the 1980s reflected a gradual substitution of wheat for corn in livestock feed rations. During the 1980s, corn feeding outside of the United States increased by 36 percent, while wheat feeding increased by 48 percent. In the United States, 78 percent of the corn consumed domestically goes to animals. That percentage, however, has slowly declined since the early 1970s, when feed use accounted for 90 percent of domestic corn consumption.

Although domestic corn feeding has increased by more than one-third since the mid-1970s, it has not kept pace with other uses. The amount of corn used in the United States for food and industrial purposes grew from about 13 million tons in 1975–76 to just over 33 million tons in 1990–91, representing an eightfold increase in production of high-fructose corn syrup and a threefold increase in alcohol production.

Corn supply exceeded demand in the mid-1980s. The inventory of corn in the United States at the end of the 1986–87 marketing year (September 1 through August 31) reached a record 124 million tons. Stocks accounted for nearly 66 percent of total annual consumption. Government programs directed at reducing production and increasing exports, along with the severe drought of 1988, sharply decreased U.S. stock levels. Stocks at the end of the 1991–92 marketing year are projected at 27 million tons, representing about 14 percent of total annual use. Corn owned by the Commodity Credit Corporation or held in the Farmer-Owned-Reserve Program peaked at 70 million tons in 1987. Those stocks will be virtually eliminated in 1992. Stocks of corn held outside of the United States were relatively stable at nearly 37 million tons in the late 1980s. Increasing stocks in China, however, will push that total to nearly 50 million tons in 1992.

U.S. corn prices were highly variable in the 1980s, reflecting extreme drought conditions in 1980, 1983, and 1988 and excellent growing conditions in 1985, 1986, and 1987. The average farm price of corn varied from a low of $1.50 per bushel during the 1986–87 marketing year to a high of $3.21 per bushel during the 1983–84 marketing year. Prices stabilized, however, from 1989 through 1991 at about $2.40 per bushel on average.

The slowdown in world consumption and trade of corn during the past ten years has increased emphasis on retaining a competitive position in the world market. Legislation in 1985 significantly lowered the support price for corn, a measure designed to make U.S. corn competitively priced. Producers and legislators recognized the importance of the export market in maintaining prices in the face of increasing productivity. This has led to a reexamination of the role of quality in maintaining satisfied customers around the world. These include Japan, the largest importer of corn, which consumes 27 percent of all imports. The former USSR is the second largest importer, followed by South Korea, Taiwan, and the Netherlands (Figure 4). These four countries swallow up 57 percent of the world's corn imports.

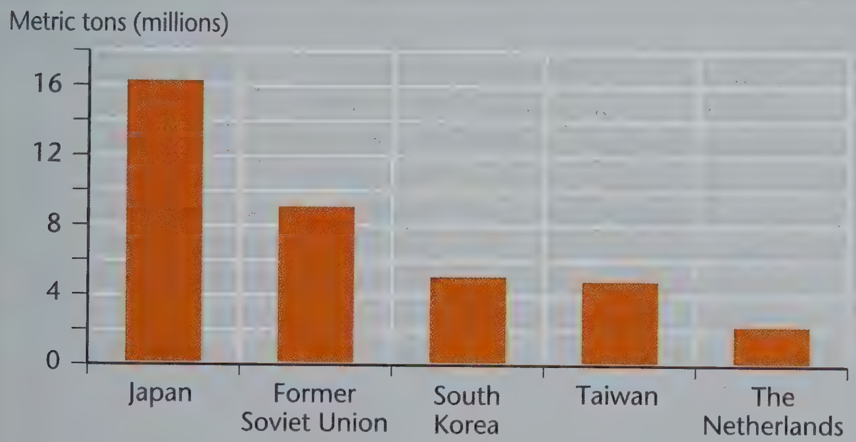


Figure 4. World corn imports, 1991.

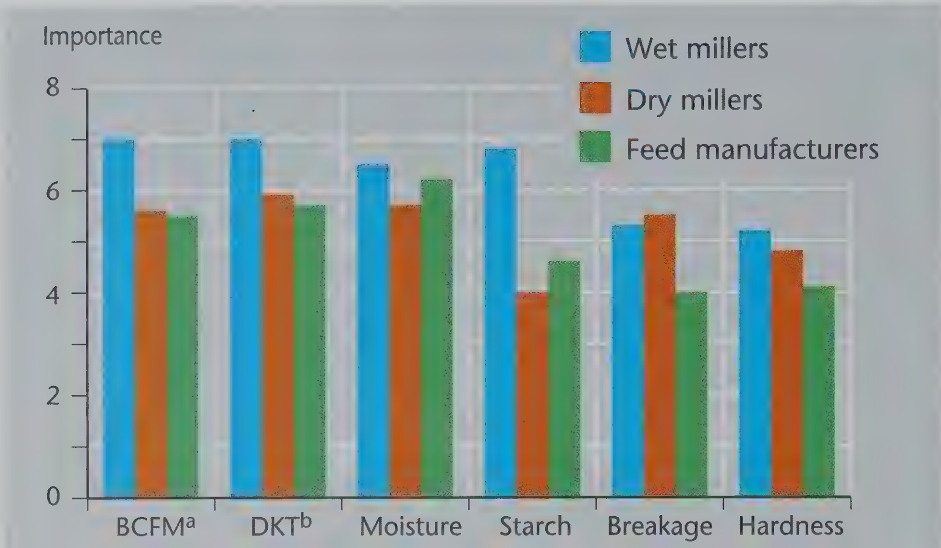
Note: World imports totaled 62 million metric tons.

Redefining Quality

Quality has therefore become a major concern not only as a reaction to complaints by foreign buyers but also in an attempt to regain lost market shares. Quality issues in Congress and in the industry have focused on changes in grades and standards. However, quality is much more than grades or the factors included in the official standards. Quality is a reflection of the value of different lots of corn in their use as final or intermediate products. Quality of the raw grain is determined by the quantity and quality of the products that can be obtained from it. Consequently, the characteristics of importance differ by the user and by the intended end use.

The major users in the domestic and international markets are feed and industrial processors. Direct use as food or in food products is a relatively small but important industry. The relative importance of each industry differs by country. Some importing countries rely on U.S. corn primarily for food (for example, Mexico), whereas others rely on it mainly for feed (for example, Venezuela). Still others use a relatively large volume for industrial processing into starch (for example, Japan).

Each of these industries desires somewhat different quality characteristics because the process technology and the final products differ. The wet-milling industry is looking for a high yield of starch. The feed industry is looking for nutritive value such as protein and carbohydrates. The dry-milling industry is looking for physical attributes (in con-



[a] Broken corn and foreign material. [b] Total damaged kernels.

Figure 5. How corn processors rank grain quality characteristics.

trast to chemical attributes) that will generate a high yield of flaking grits.

Commonalities also exist among the three major industries using corn. In an international survey of corn processors, firms in all three industries ranked moisture, foreign material, and damage as the most important characteristics (Figure 5). Both dry millers and wet millers rated breakage susceptibility above 5.3 on a scale of 1 (least important) to 7 (most important).

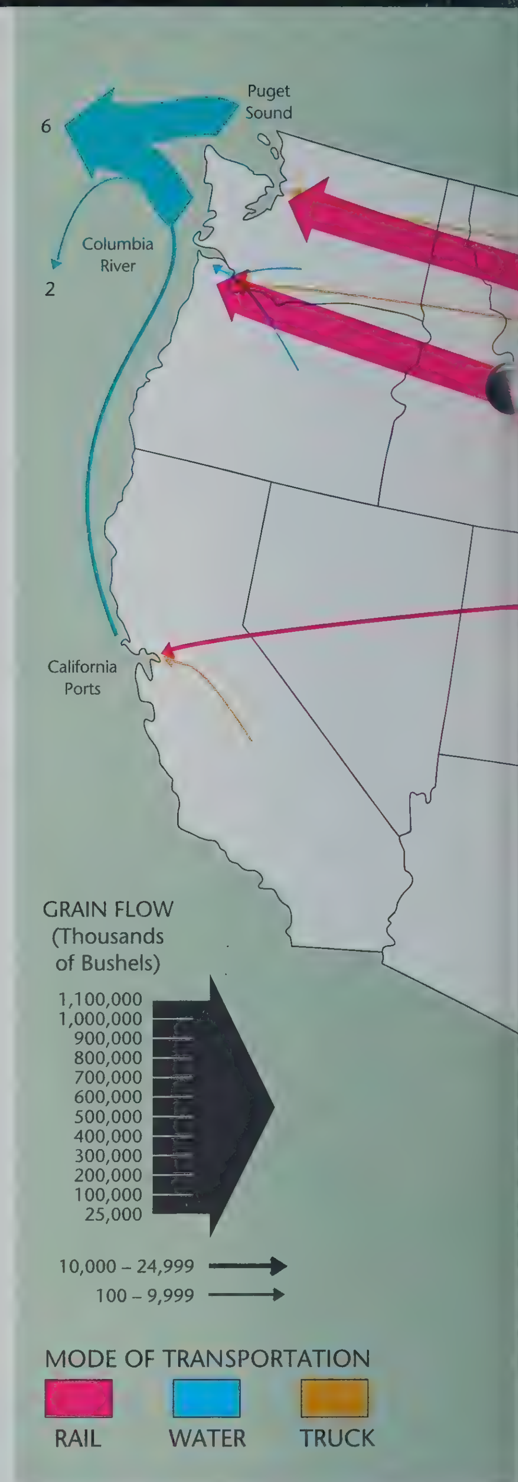
Tuning In to Users' Needs

Opportunities exist for Illinois' corn producers and marketing firms that can recognize the needs of each of the primary users. A desirable quality characteristic for both wet millers and dry millers, low breakage susceptibility can be achieved by reduced-temperature drying, genetic selection, and special harvesting methods. Although some U.S. dry millers can use producer contracts to obtain the desired quality, this strategy is too expensive for foreign buyers to use. The long marketing channel between farm and foreign processing plant is too complex and convoluted for identity-preserved shipments to be economically feasible for most commercial users.

The alternative is to use contracts specifying the desired characteristics so that buyers may purchase and segregate according to those quality factors. For example, more than 15 percent of Illinois farmers are using low-temperature drying techniques that generate high-quality corn at the farm. In years of good harvest weather, an even higher percentage of their corn can be dried naturally in the field. The quality and value of this corn is equal to the best that South Africa and Argentina can deliver. However, the traditional market channel that bases price on numerical grade creates an incentive to blend different qualities to meet numerical grade without regard to the effect on product yields.

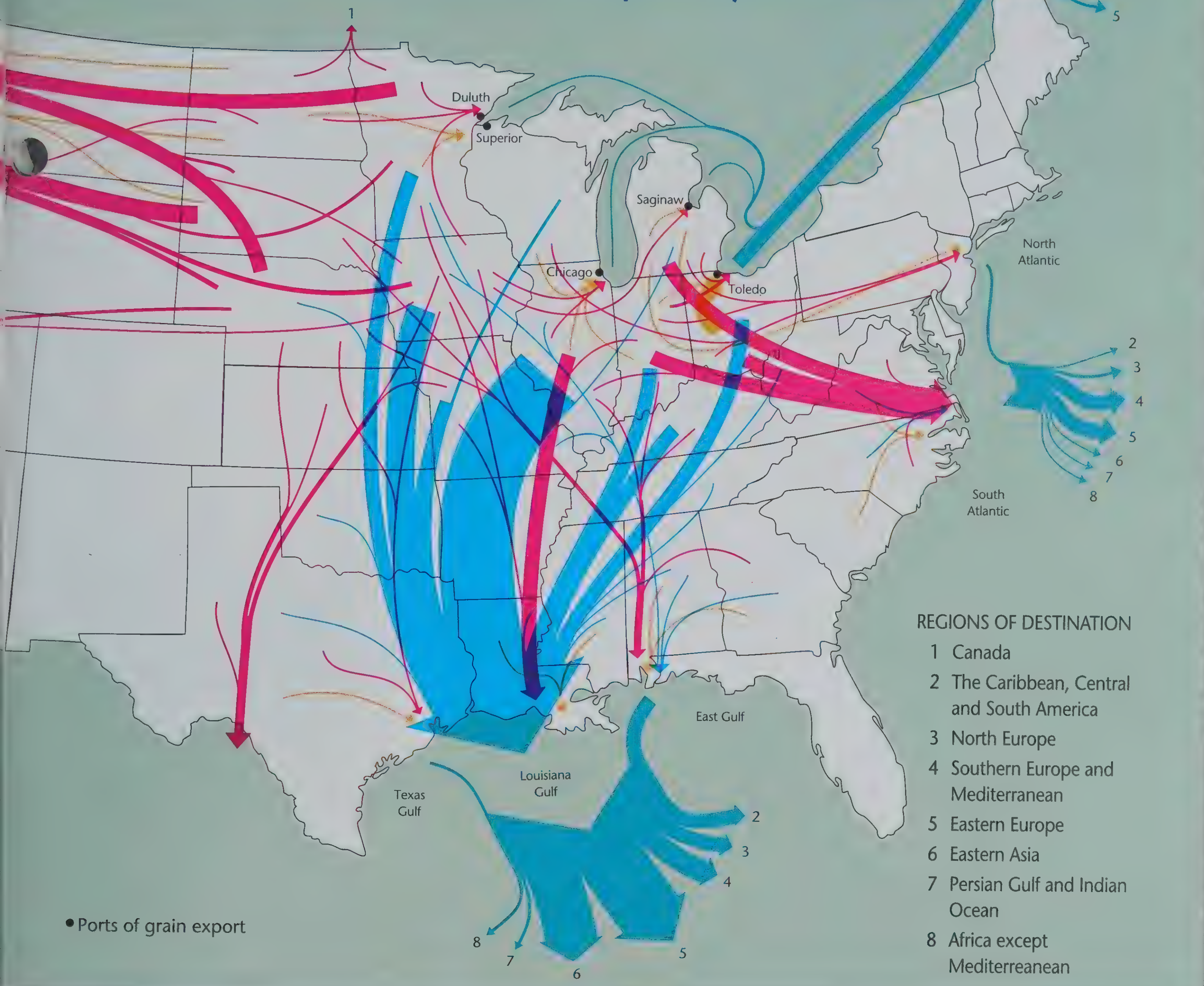
The University of Illinois, in conjunction with several exporters, has demonstrated that better-quality corn can be moved through the market channel at a relatively small additional cost by specifying the desired characteristics at the country elevator, river elevator, or export elevator. With price differentials attached to these characteristics, the market system provides segregation through the market channel without the necessity of containerization at the farm or identity-preserved shipments. Any corn meeting the required specifications receives a price differential and is loaded to meet that contract.

Although demonstration shipments have identified the physical and eco-



nomic feasibility of such a system, problems still exist. For example, with only small volumes of the higher-quality corn moving into the export market channel, it becomes more expensive to handle, segregate, and load the vessel. If less than a full vessel is purchased, there is a cost of coordinating the remainder of the shipment of normal-grade corn going into the export market. Matching buyers willing to pay premiums with farmers and shippers willing to segregate better quality, while maintaining the efficiency

Corn Movements to Points of Export by All Modes



of arbitrage and a choice of sellers, is another challenge.

If a larger demand for superior quality with attached premium were available, farmers would respond with an adequate supply. Until the supply has been generated and demonstrated to be available on a regular basis at competitive prices, however, it will be difficult to find buyers willing to make the necessary commitment to pay the premiums. The development of both supply and demand must be made jointly and will require time to mature. Quality differences beyond those reflected by numerical grades exist in the market channel. A few buyers have found strategies for directing those qualities into their plant. Changes in grades and producer incentive can encourage the rapid development of a larger premium market.

The versatility of corn makes it an excellent commodity for the development of new products and uses. Its importance in the economy of Illinois requires that quantity and quality of the crop be given a high priority in the research and development plans of farmers as well as the University of Illinois. The research reports in this publication identify some of the effort being made to assure that the needs and preferences of foreign and domestic customers are being met and that satisfied customers and competitive prices will continue to be the goal of the U.S. corn industry.

Darrel L. Good, professor, and Lowell D. Hill, L.J. Norton Professor of Marketing, Department of Agricultural Economics ■

Newly developed machine vision provides a tool for the inspection of grain. With this new technique, defects such as pericarp cracks and stress cracks are clearly displayed on a computer screen. Stress cracks indicate that corn may not hold up well during shipping and that starch yield may have been reduced, problems caused by improper grain drying.

Measuring Corn Quality

Several quality factors affect the suitability of corn for each of its primary uses — dry milling, wet milling, and feeding. Obviously, moisture content, low percentages of damaged kernels, and absence of mycotoxins are always important. But beyond these factors, different tests are needed to match corn lots to their most suitable use.

The most important factor for determining suitability for dry milling is kernel hardness, which is influenced primarily by variety. The harder the kernel, the higher the yield of large flaking grits, which are needed for making certain food products. Generally as corn hardness increases, kernel density increases, test weight increases, and the kernel exhibits a greater resistance to grinding.

Tests measuring true kernel density work well for determining hardness. Densities range from 1.19 to 1.31 grams per cubic centimeter at about 15 percent moisture content. Hard corn will typically have densities above 1.27 grams per cubic centimeter.

The critical factor for determining suitability for wet milling is whether protein has been denatured — a nonreversible change inhibiting separation of starch from protein — due to an excessively high drying temperature. For wet milling, kernels are steeped in sulfur dioxide (SO_2) for 20 to 38 hours at 122° to 131°F. Then germs and fiber are separated, leaving a starch-gluten slurry. Kernel drying temperatures above 140°F modify the protein, leading to reduced starch yield. As an approximate rule, as kernel temperature increases by 10°F over 140°F, starch yield decreases by 1 percentage point.

One way to determine protein denaturation is the ethanol soluble protein test. A faster, but indirect, way is to candle a representative sample for stress cracks. Stress cracks are tiny fissures in the center of the kernel propagating radially outward but not extending through the seedcoat. Severity of stress cracking increases as speed of moisture removal increases during drying, which is usually indicative of high-temperature drying. Generally, samples with fewer than 25 percent of the kernels showing stress cracks will have high starch recovery.

Machine vision, a technique being developed in the UI Department of Agricultural Engineering, alleviates the tedious and time-consuming task of candling. Using this new method, inspectors can detect stress cracks by analyzing computer-generated images of the corn kernels rather than visually inspecting the actual kernels.

Broken corn, the result of improper drying methods and rough handling, is defined as that passing through a 12/64-inch round-hole sieve.

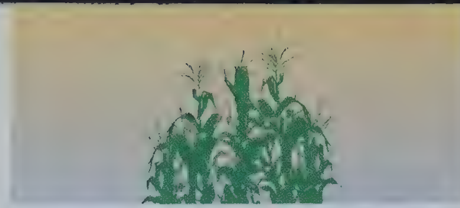
Excellent corn, with fewer than 25 percent stressed-cracked kernels, can be obtained using natural-air or low-temperature drying. For increased drying speed, combination drying where the moisture below 20 percent is removed with low-temperature drying can be used. If higher drying capacity is needed, concurrent flow dryers with tempering should be considered. The concurrent flow exposes the wettest grain to the highest temperatures and the driest grain to the lowest, and the tempering allows periodic cessation of drying to allow moisture to distribute more uniformly within the kernels and thus minimize stress cracking.

For poultry and livestock feeding, chemical constituent contents are very important. Feed rations tailored to the protein content available in a corn lot can save money. Near infrared reflectance (NIR) units provide protein, oil, moisture, starch, and fiber contents on representative ground samples in about 30 seconds. NIR operates on the principle that selected wavelengths of light are absorbed in proportion to the quantity of a constituent present. NIR equipment is very reliable; however, uniform grinding procedures and good calibrations to chemistry values are essential.

Recently, near infrared transmittance (NIT) equipment has become available to measure protein, oil, and other constituents on whole-kernel samples. Because most of our annual corn production is used as feed and timely harvest often requires high-speed drying (decreasing its suitability for dry milling or wet milling), the optimal use of high-temperature–dried corn would be for feeding to livestock.

For all uses, breakage is also an important factor. It is the most common factor that lowers grade for U.S. No. 2 to No. 3, resulting in a lower dollar value and diminished suitability for storage. In both dry milling and wet milling, broken corn goes into a feed byproduct with a value below that paid for the raw corn. Breakage during handling is always cumulative and is a common complaint of foreign buyers. It is easily measured by sieving corn over a 12/64-inch round-hole sieve and can be reduced by less handling, using equipment that reduces impact velocities, and drying methods that reduce breakage susceptibility.

Regardless of the use, cleaning of corn is a good practice because the removal of fine material leaves the grain mass more porous, allowing more uniform airflow and less resistance to airflow during drying and aeration during storage. In-bin drying costs can easily be cut by 1 to 2 cents per bushel by cleaning the grain. *— Marvin R. Paulsen, professor, Department of Agricultural Engineering*

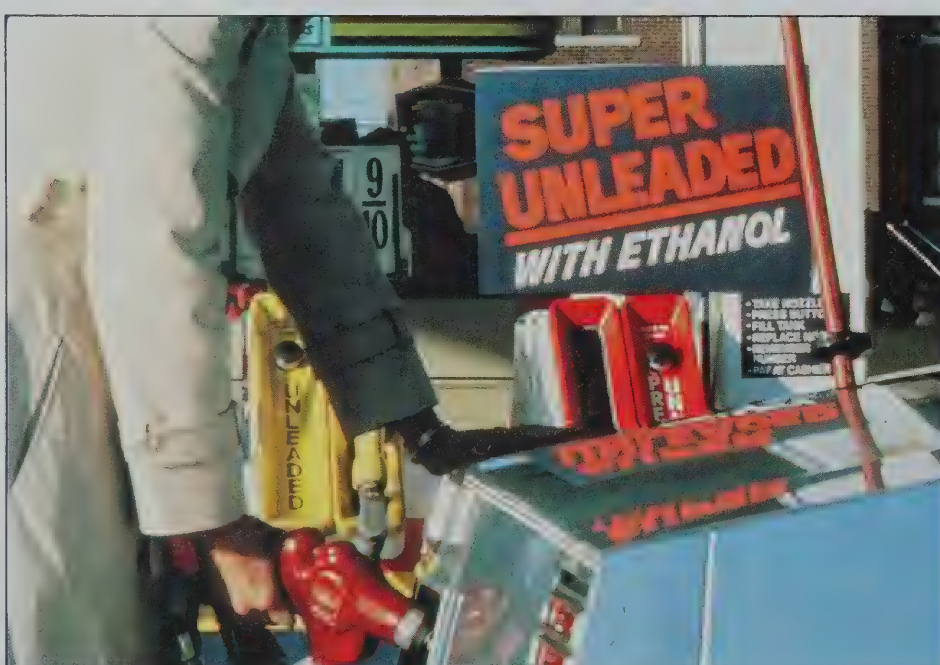


Tapping a Renewable Energy Source

Carroll E. Goering

The United States has a long history of using corn as fuel. Prior to the introduction of field shelling in the 1950s, each farm acquired a pile of corn cobs whenever the corn crop was shelled from a crib; the cobs made an excellent fuel for the cookstoves of that era. During the Great Depression, when a unit of heat energy from ear corn became cheaper than a unit of heat from coal, Professor Emil Lehman, then head of the Department of Agricultural Engineering at the University of Illinois, produced an Extension circular on using ear corn as fuel. More recently, a number of manufacturers have introduced stoves designed to burn shelled corn. By far the largest commercial use of corn as fuel, however, is through conversion of the starch in corn to ethanol.

Production of ethanol begins with wet milling to break the corn kernels into their constituent parts. Each bushel of shelled corn contains approximately 32 pounds of starch, which is converted to sugar and fermented into a beer containing approximately 10 percent ethanol. The beer is then distilled, and the water remaining in the distillate is absorbed to recover anhydrous (water-free) ethanol. With current technology, 2.5 gallons of anhydrous ethanol can be produced from each bushel of corn.



The federal Clean Air Act mandates that 40 cities with the worst air pollution and ozone problems use ethanol-gasoline blends in the winter, when the risk of damage from carbon monoxide is greatest. Such blends produce less carbon monoxide than pure gasoline.

The Ethanol-Gasoline Blend

The largest use of corn-based ethanol today is for mixing with gasoline in a 10 percent ethanol–90 percent gasoline blend, and a number of factors are driving this use. An initial boost was provided in 1978, when the U.S. Congress passed a law exempting blenders from six cents of the federal highway tax for every gallon of fuel containing 10 percent ethanol and 90 percent gasoline. The law was revised in 1990 to extend the tax-exemption program to the year 2000 and to reduce the blenders' exemption to 5.4 cents; the 0.6 cent difference is being put into a fund to help establish new ethanol plants of up to 30 million gallons' annual capacity. Some states are enhancing these federal incentives through their own tax breaks. In Illinois, which leads the nation in ethanol production, fuel ethanol sales are exempt from 2 percent of the state sales tax. Another factor encouraging the use of ethanol-gasoline blends is the ability of ethanol fuel to burn cleanly and not damage the environment. Nationally the ethanol fuels industry has responded by growing from 10 million gallons of annual production in 1978 to 900 million gallons in 1989.

Ethanol fuel has an octane rating above 100. Octane rating is a measure of the knock resistance of a fuel. Motorists are familiar with the pinging or knocking that can occur when a spark-ignited engine is accelerated. Pinging or knocking is audibly annoying and, in time, can damage the engine. Prior to 1972, most gasolines contained 1 gram per gallon of

tetraethyl lead (TEL), an additive used to raise the octane rating. When all new cars sold after 1972 were required to have catalytic converters to reduce exhaust emissions, it was necessary to introduce lead-free gasoline because TEL damages the catalytic converters. Leaded regular gasoline continued to be sold for use in older cars until it was found that the lead emissions from tail pipes were themselves an environmental hazard. By 1988, federal regulations required the elimination of TEL from all gasoline.

The phaseout of TEL meant that other means had to be found to raise gasoline octane ratings to acceptable levels. The use of 10 percent ethanol in gasoline provided an increase of approximately 3 octane numbers, about the same gain that could be provided by 1 gram per gallon of TEL. Thus, the need to boost octane provided a further incentive for the use of ethanol fuels.

Passage of the Clean Air Act by Congress in 1990 is expected to further increase ethanol demand because ethanol belongs to a group of fuels classified as oxygenates. Unlike petroleum fuels that contain only carbon and hydrogen, oxygenates also contain oxygen atoms in their molecular structure. Blending oxygenates into the fuel of an engine whose fuel system has been adjusted to burn gasoline is a way of reducing carbon monoxide emissions. The extra oxygen is able to convert part of the carbon monoxide into carbon dioxide, a nontoxic gas. There is concern that buildup of carbon dioxide in the atmosphere will contribute to global warming through the greenhouse effect. But because carbon dioxide is extracted from the atmosphere through photosynthesis by growing corn plants, ethanol fuels are in a closed carbon cycle and thus provide no net contribution to carbon dioxide buildup.

The Clean Air Act identified some 40 U.S. cities with unacceptably high carbon monoxide levels. Beginning next winter, the gasoline sold for winter use in those cities must contain 2.7 percent oxygen by weight. Further, by 1995 gasoline sold at any time in the nine U.S. cities with the worst ozone problems will have to contain at least 2 percent oxygen.

Ethanol will be competing with a number of other oxygenates in supplying the required oxygen to gasoline blends. The four most promising contenders are ethanol, methanol, MTBE (methyl tertiary butyl ether), and ETBE (ethyl tertiary butyl ether). Table 1 shows the oxygen content of each of these oxygenates. Methanol has the highest oxygen content of the four oxygenates listed. Because of its corrosiveness, however, automobile manufacturers will not honor new-car warranties if blends containing more than 5 percent methanol are used as fuel. In contrast, new-car warranties are honored for fuel blends containing 10 percent ethanol. Thus, when used at the maximum allowable concentrations in blends with gasoline and when differences in fuel densities are considered, ethanol can provide a blend containing 3.67 percent oxygen, whereas methanol can provide 2.68 percent oxygen in the blend. The ethers listed in the table are derivatives of the respective alcohols; thus MTBE is derived from methanol and ETBE from ethanol.

Changes in engine design can reduce exhaust emissions. For example, some late-model cars include an oxygen sensor in the exhaust system. The signal from the sensor is used to control the richness of the fuel-air mixture entering the engine; that is, the mixture is made richer if too much oxygen appears in the exhaust gas and vice versa. In such cars, the mixture control system tends to correct for the presence of oxygen in the fuel, thereby diminishing the effect of the oxygenates on exhaust carbon monoxide. The oxygenated fuels are thus most effective in the many older vehicles that do not have oxygen sensors in the exhaust system. All of the oxygenates in Table 1 serve as octane boosters, and this function will continue to be useful even if all cars are eventually equipped with oxygen sensors.

Table 1.
Comparison of oxygenates

Oxygenate	Percent oxygen
ETBE[a]	15.7
MTBE[b]	18.2
Ethanol	34.8
Methanol	50.0

[a]Ethyl tertiary butyl ether.
[b]Methyl tertiary butyl ether.

Because carbon dioxide is extracted from the atmosphere through photosynthesis by growing corn plants, ethanol fuels are in a closed carbon cycle and thus provide no net contribution to carbon dioxide buildup.

How It Affects Engine Performance

Will alcohol damage an engine or degrade its performance? Before answering this question, it is important to distinguish between the two strongest contenders for the alcohol fuels market: ethanol and methanol. Methanol is more corrosive and thus potentially more damaging to an engine than ethanol. Two properties of ethanol, its solvent power and its volatility, must be considered in answering the question about its effect on engines. Ethanol is a stronger solvent compared to gasoline, and materials in the fueling system must be able to resist being dissolved by the fuel. In the mid-1970s, materials in the fueling system of gasoline-powered engines were upgraded to withstand the solvent power of ethanol; fuel systems in vehicles manufactured since then are not at risk.

Corn as Chemical Feedstock

Ethanol is only one of several chemicals that can be manufactured from corn. Others include

- Acetone and butanol, which are high-value industrial solvents.
- Butanediol, an industrial solvent and a precursor to synthetic rubber.
- Lactic acid, valuable by itself as a commodity chemical, but also in the future as a raw material for polylactates and acrylates, which are biodegradable polymers useful in packaging and medicine.
- Acetic acid, the main component of vinegar, but which has much greater potential as an environment-friendly, noncorrosive highway deicer in the form of calcium-magnesium acetate (CMA), to replace the chloride salts now used to clear roads in the winter. If even half the salt used on the nation's highways were replaced with CMA, the demand for corn would increase by 100 million to 300 million bushels annually and create a $1 billion to $3 billion market for a new corn-based product.
- Citric acid, a major acidulant in food products, which is used in industrial detergents as metal finishing and cleaning solutions. Much of the citric acid available in the United States today is produced by two large corn refiners.

Fermentation of hydrolyzed cornstarch, or dextrose, is the heart of the manufacturing process. A technical constraint, related to biological limitations, is because of the enzymes and microbial cells used in the conversion of corn. For example, yeast (*Saccharomyces cerevisiae*) is used for ethanol; bacteria such as *Lactobacillus delbreuckii* for lactic acid; *Clostridium acetobutylicum* for acetone and butanol; and *Clostridium thermoaceticum* or *Acetobacter aceti* for acetic acid. Frequently, the "wild" strain of the microorganism found in nature is inefficient in that it produces the chemical too slowly (for example, ethanol fermentation typically takes 24 to 48 hours, acetic acid fermentation 36 to 200 hours) and in too low a concentration (for example, ethanol is 10 percent of the fermentation mixture, acetic acid only 2 to 10 percent, acetone-butanol 1.5 percent). These inefficiencies result in high fermentation and downstream processing costs, the latter for removing large quantities of water and for purifying the chemical. (In contrast, petroleum refiners essentially start with 100 percent product in the crude oil: they simply have to distill the oil by heat and blend the fractions to obtain the desired products).

Industrial microbiologists and biochemical engineers are addressing the inefficiencies in producing fuels and chemicals from corn. Genetic engineering can result in microorganisms with improved biosynthetic capabilities. Researchers at the University of Illinois have developed strains of *Clostridium acetobutylicum* that now produce twice the concentration of butanol of parent strains, and *Clostridium thermoaceticum* has been mutated and improved to produce four times' higher concentration of acetate than the parent wild strain.

Similarly, UI biochemical engineers have designed continuous bioreactors with productivities that are 10 to 20 times higher than the technology used today. In addition, modern separation techniques based on synthetic membranes are expected to dramatically change the way in which twenty-first century corn refineries operate.

Although these technologies will improve the manufacturing process, the economics will depend to a large extent on factors beyond the control of microbiologists and engineers. The corn itself contributes 50 to 60 percent of the cost of ethanol and 20 to 30 percent of the cost of organic acids. Energy, much of it produced by coal and natural gas, probably accounts for another 15 to 25 percent of the total corn-refining cost. The prevailing price of oil on the international market has much to do with the economics of corn-based versus petroleum-based chemicals. Today the balance tilts in favor of the latter because of the low price of oil ($26 per barrel). However, petroleum is a finite resource that is largely imported, whereas corn is annually renewable and available in abundance within our own borders. One must also consider the military and political consequences of keeping imported oil available at low cost.

Considering these factors, and with continued technological advances, the cornfields of the Midwest could be as important a source for fuels and chemicals in the future as the oil fields of the Middle East are today. — *Munir Cheryan, professor of food and biochemical engineering, Department of Food Science*

The fuel tank is also a potential problem area for fuels containing ethanol. Water condensing from moisture-laden air can accumulate in the tank. Heavier than gasoline, the water settles to the bottom. Because ethanol is hygroscopic (water-absorbing), it can link the water to the gasoline fuel in the blend and cause it to move through the fuel line. Also, the solvent power of ethanol allows it to remove rust and dirt accumulated in the fuel tank of an older vehicle. Thus, during the first use of an ethanol-gasoline blend in an older vehicle, the water, rust, and dirt moving through the fuel line can plug fuel filters and stall the engine. After the water, rust, and dirt are removed, however, the ethanol in the blend will help to keep the tank clean.

The volatility of fuel for spark-ignited engines is important because the fuel must vaporize and mix with air before it will burn. If the fuel volatility is too low, not enough fuel will vaporize to start a cold engine. If the fuel is too volatile, it can vaporize in the fuel line and form bubbles that render the fuel pump ineffective; such a "vapor-locked" engine will not run. Gasoline is a blend of many dif-

ferent hydrocarbons that vaporize over a range of temperatures. The petroleum industry adjusts the blend throughout the year in accordance with temperature changes; the blend is made more volatile in the winter for easier starting and less volatile in the summer to avoid vapor lock. Adding ethanol to gasoline increases the volatility of the blend. The fuel blender provides a volatility suitable for the season. The gasoline used in the blend should have a volatility low enough to accommodate the increased vapor pressure introduced by the addition of ethanol.

Historically a carburetor accomplished the fuel and air mixing in gasoline-powered engines. By the late 1980s, electronic fuel injection (EFI) had largely displaced carburetors. With EFI, injection nozzles are used to spray fuel into each intake valve port of the engine. The tiny holes in the injection nozzles are easily blocked, thus reducing the output power, stalling the engine, or both. The nozzle-plugging problem was solved by adding a detergent to the fuel to keep the nozzles clean. Manufacturers of fuel ethanol routinely add enough detergent to protect the entire ethanol-gasoline blend.

Let us return to the question of whether alcohol will damage an engine or degrade its performance. Now that such blends have been in widespread use for more than a decade, the potential problems have had an opportunity to appear. The problems have been solved to the satisfaction of the automobile manufacturers, all of whom will continue to honor new-car warranties when blends of 10 percent ethanol–90 percent gasoline are used as fuel. Manufacturers will also honor their warranties if methanol-gasoline blends are used, but only if the amount of methanol does not exceed 5 percent of the blend.

Energetically Viable?

Ethanol fuel has been criticized on the basis of poor energetics, the assertion being that more energy is required to produce ethanol than can be obtained by burning it. In one sense, such a charge only recognizes thermodynamic reality, that is, all processes are done at an energy cost. For example, more energy flows into a petroleum refinery than can be obtained by burning the products from the refinery. Nevertheless, refineries are worthwhile energetically because the refinery products represent a higher grade of energy than the crude oil from which they are made. The criticism of ethanol would be valid if ethanol production resulted in a net loss of high-grade energy. In the rush to cash in on public interest in ethanol in the 1970s, some ethanol production plants were built that were not justifiable on an energetics basis. In the past decade, however, much research and engineering has gone into improving the energy efficiency of ethanol production.

Table 2 summarizes the energy flows in ethanol production. Although crop production practices vary from farmer to farmer, the values in the table are easily achievable with current technology. All energy costs were included in the 7.7 million BTUs required to produce the crop, including the energy costs of manufacturing the farm machinery. Nitrogen fertilizer constitutes the largest component of corn-production energy. Diesel fuel used in the farm equipment is the second largest component. The energy credit for the coproducts was calculated as the sum of the heating values of the corn oil and protein; in fact, these coproducts are not burned because their economic value is much greater as food and feed than as fuel. The table shows an energy ratio of 2.26, that is, 2.26 units of energy returned for each unit of high-grade energy invested. The net gain does not violate thermodynamic laws because the solar energy captured by photosynthesis is low-grade energy and was excluded from the calculations.

Table 2.
Energy flows in ethanol production from one acre of corn, and return on investment of high-grade energy

	Energy requirements (million BTUs)	
Production of 105 bushels of corn from 1 acre	7.70	
Processing the corn into ethanol and coproducts	12.51	
Total energy input, excluding photosynthesis		**20.21**
224 pounds of corn oil	3.84	
1,129 pounds of corn gluten	6.64	
Subtotal for coproducts (energy credit)		**10.48**
Net energy cost of ethanol produced		**9.73**
Energy in 263 gallons of ethanol produced		**22.00**

Energy ratio = 22.00/9.73 = 2.26 units of energy returned for each unit of high-grade energy invested

Some raw material other than shelled corn will need to be found if ethanol is to supply a substantial portion of our transportation fuel.

Market Potential

How large can the ethanol fuel market grow? A number of factors affect growth potential, including availability of raw material, total capacity of the nation's ethanol production plants, market capacity for the coproducts, and market capacity for the ethanol. Over the next 10 years, national production of ethanol is projected to more than double as annual consumption grows to more than 2 billion gallons. But that 2 billion gallons, generating 20 billion gallons of ethanol-gasoline blended fuel, would not begin to saturate the fuels market. The United States uses more than 100 billion gallons of gasoline annually. To produce 2 billion gallons of ethanol annually would require the starch from 0.8 billion bushels of corn, or approximately 10 percent of the nation's annual corn crop. It should be possible to expand total plant capacity to produce 2 billion gallons of ethanol annually by the year 2000. For each gallon of anhydrous ethanol, 4.3 pounds of corn gluten are produced. Growth in production of the corn gluten coproduct would come at the expense of soybean meal, which competes for the same feed market.

In the longer term, it will be necessary to replace petroleum fuels entirely. Domestic production of petroleum is declining, and as consumption continues to increase, the shortfall is made up from imports. In 1990, 42 percent of the petroleum consumed by the United States was imported. The U.S. Office of Technology Assessment estimates that, at the current growth rate, 75 percent of U.S. petroleum needs will be imported by the year 2010. Meanwhile, the total world resource of petroleum continues to be depleted. The remaining length of the petroleum era is primarily dependent upon how well the growth in petroleum demand can be constrained, but petroleum availability is unlikely to extend much beyond 2080.

Although nearly all U.S. fuel ethanol is blended at a 10 percent concentration into gasoline, larger proportions of ethanol are possible. By suitable adjustment of the fuel-air ratio, spark ignition engines will run well on 100 percent ethanol, though starting is a problem with such engines. Because ethanol is a pure compound, it has a single boiling point, and not enough will evaporate in cold weather to form a combustible fuel-air mixture. A solution to the problem has been to use E85, a blend containing 85 percent ethanol and 15 percent gasoline. The gasoline in the blend can evaporate and form combustible mixtures in winter temperatures. Some automobile manufacturers have already built a limited number of cars designed to run on E85 fuel, and the state of Illinois has purchased some of these cars for trial.

Ethanol's high octane rating hinders its use in compression ignition (diesel) engines. High octane signifies strong resistance to self-ignition and knock, but a fuel must self-ignite to burn in a compression ignition engine. Techniques developed to overcome this problem include modifying the engine to provide an ignition source or adding an ignition accelerator to allow the ethanol to self-ignite. The use of ethanol (or methanol) as fuel in compression ignition engines virtually eliminates particulate (smoke) emissions from the exhaust. Federal regulations taking effect in 1991 and 1994 place increasingly stringent limitations on such emissions from city busses and highway trucks.

How large a role can ethanol play in the replacement of petroleum? Clearly corn-based ethanol cannot supply the entire gasoline market. Assuming historic trends in corn planting continue, converting the starch in the entire annual corn crop would provide approximately 20 billion gallons of ethanol. A gallon of gasoline contains 50 percent more energy than a gallon of anhydrous ethanol. Thus, 20 billion gallons of ethanol would replace only 13.3 billion gallons of gasoline, or less than 13 percent of annual consumption. Some raw material other than shelled corn will need to be found if ethanol is to supply a substantial portion of our transportation fuel.

Research is under way to expand the feedstock base for ethanol production. In the laboratory, it is already possible to process cellulose into fermentable sugars from which ethanol can be made. If the process becomes commercially viable, it will be possible to use cornstalks (as well as other crop residues, and even wastepaper) as feedstocks for ethanol production. The U.S. Department of Agriculture estimates that as many as 200 million acres of cropland could be made available for energy crops in the next 50 years. Enough ethanol could be produced from the biomass grown on these acres to supply more than half the fuel now used for transportation vehicles.

Currently ethanol from cornstarch is making an important contribution to the nation's fuel needs. Blended at a 10 percent concentration into gasoline, it boosts octane and helps reduce exhaust pollutants. The starch in approximately half of the annual corn crop would be required to convert the entire annual gasoline supply into such a blend. By the time the global petroleum resource is depleted less than a century from now, alternatives will need to supplant petroleum fuels. The fuels market is far too large to be supplied entirely by ethanol derived from cornstarch, but if cellulose-conversion technology can be commercialized, cornstalks and other cellulosic materials can be used to produce more than half of our annual transportation fuel.

Carroll E. Goering, professor, Department of Agricultural Engineering ■

Development and Adoption of Hybrid Corn

G.F. Sprague

The development and adoption of hybrid corn, followed by its rapid and ongoing improvement, has spurred more agricultural productivity in this century than any other factor.

After hybrids became available in the early 1900s, farmers quickly adopted the new idea. In 1930, less than 1 percent of U.S. corn acreage was planted to hybrid corn. But by 1945, nearly 90 percent of corn grown in the Corn Belt was hybrid. And the rest of the country was not far behind (Figure 1).

A New Idea

Many techniques were used to urge farmers to adopt the new corn, including articles in *Farm Journal*, *Wallaces Farmer*, and other farm journals; hybrid corn short-courses, often sponsored by the Cooperative Extension Service; and yearly reports of the so-called state corn yield test. Possibly the most effective, however, was direct side-by-side (hybrid and variety) comparisons in the fields of farmers who first tried the new product.

After seeing the potential of hybrids, farmers found adoption of the innovation to be quite straightforward. It involved a simple single-stage substitution, the replacement of open-pollinated varieties by hybrids into a then stable production system.

Although adoption was most rapid in the major corn-producing states, states where corn was a relatively minor crop quickly followed suit. By 1960 essentially the entire U.S. corn acreage was planted to hybrids.

The increasing demand immediately raised the question of how hybrid seed would be produced. Would farmers produce it as a sideline to their regular operations, or would production be concentrated in large companies specializing in seed production? Both avenues were explored.

By 1923 several farmers were experimenting with seed production using parent stock provided by Henry A. Wallace, one-time editor of *Wallaces Farmer,* who was also a former Secretary of Agriculture and an early developer of corn hybrids. Later, when the future of hybrids became apparent, some of these operations were consolidated to establish Pioneer Hi-Bred (now Pioneer Hi-Bred International, Inc.). Other seed companies such as Funk Bros. of Bloomington (now Ciba-Geigy Seed Division of North Carolina) and DeKalb Agricultural Association (now DeKalb Plant Genetics) had the production and sale of open-pollinated varieties as a part of their seed operations. In such cases, the transition from producing open-pollinated seed to hybrid seed was relatively simple.

Many farmers explored the possibility of producing their own hybrid seed. Some of them already had experience in the production and sale of open-pollinated varieties. But many of these individual attempts at hybrid seed production failed largely due to the conflict of peak labor

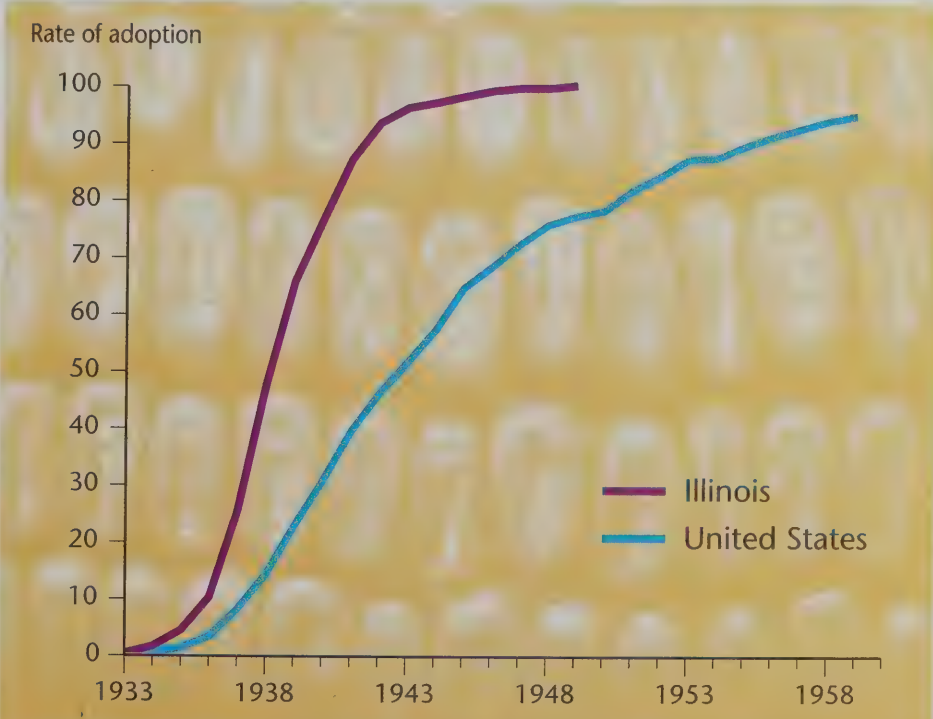


Figure 1. Rate of adoption of hybrid corn in Illinois and the United States.

Maize Genetics Stock Center

Few service-oriented programs in science can point to an uninterrupted operation of more than 60 years' duration. Such a project is the Maize Genetics Stock Center, housed in the Department of Agronomy at the University of Illinois.

In essence, the stock center serves as an intermediary in assisting maize geneticists in the exchange and sharing of genetic stocks among themselves. Seed samples submitted by individual geneticists are perpetuated systematically by the project and are made available upon request to members of the maize genetics community, and others, for use in research. Each year, maize geneticists submit new gene mutations, gene combinations, or chromosome aberrations to the center for evaluation and potential addition to the collection.

The collection was begun at Cornell University in the 1920s, then was moved to the University of Illinois in 1953, where it has been continued and greatly expanded. Currently the collection consists of about 75,000 individually pedigreed seed samples produced by hand pollination and stored in packets in a walk-in cold room. Included are samples of several hundred symbolized genes maintained both singly and in multiple-gene combinations useful in research. In addition, there are about 1,000 unique chromosome rearrangements or other stocks varying in chromosome numbers.

Each of the individual gene mutations and chromosome aberrations in the collection has been assigned a unique genetic symbol by maize geneticists. Genetic pedigrees, stock listings, and seed requests are written in the form of these genetic symbols.

The collection is intended primarily to serve maize geneticists, but samples are also supplied for studies in physiology, biochemistry, molecular biology, developmental biology, and cytogenetics. Mutant traits may be studied directly to investigate blocks in metabolic pathways, or they may be used as tools for such purposes as gene mapping or marking chromosome segments in transmission. Genetic stocks represent the research tools of maize geneticists, and this project provides a service to geneticists and other biologists somewhat similar to that provided to chemists by chemical supply houses.

Although some mutations that occur spontaneously in nature are recognized and saved, most of the mutations in the collection were deliberately induced by exposure to mutagenic agents — chemicals or high-energy radiations. Many of the gene mutations and chromosome aberrations were induced in kernels exposed to atomic bomb radiations in shipboard tests conducted in the Pacific at Bikini Atoll in 1946 or Eniwetok Atoll in 1947.

The stock center is not designed to provide samples of maize germplasm or inbred lines for use in maize breeding. Variants in the collection are seldom saved with a view to their direct use in improving agricultural production or products. Most of the mutant traits are too extreme for commercial use. Rather, they are chosen primarily to serve as genetic markers in transmission studies or to cause blocks in biochemical pathways; in these uses, it is important that the traits be clearly expressed, that is, somewhat extreme.

Earl Patterson catalogs and stores samples of new gene mutations, gene combinations, or chromosome aberrations submitted by maize geneticists for use in research.

A catalog of stocks in the form of genetic symbols appears each year in the *Maize Genetics Cooperation News Letter*, edited at the University of Missouri and distributed by subscription to scientists and libraries throughout the world. This listing serves as a basis for seed requests. Typically, a 15- to 25-kernel sample is supplied in response to a specific requested item.

The maintenance of a comprehensive collection of genetic stocks at a central location guards against inadvertent loss of individual mutations and also provides a single, widely publicized source from which maize genetic stocks may be obtained. Currently, more than 200 requests for seed samples (phone calls, letters, FAX transmissions) are received each year and about 2,500 samples are supplied. About 25 percent of the samples are sent to foreign countries. — *E.B. Patterson, associate professor of plant genetics, Department of Agronomy*

demands between seed production and regular farming operations. It became apparent that hybrid seed production was a specialized undertaking. The individuals who were able to adjust their operation to include hybrid seed production persisted, and many are still in the hybrid business. Collectively they account for 15 to 25 percent of the hybrid seed currently produced and sold.

Building Better Yields

Prior to the hybrid corn era, average corn yield rarely exceeded 30 bushels per acre. Yield trends for the period of 1866–1990 are illustrated in Figure 2.

Since 1930, yields have increased steadily in an almost straight-line progression: from 30 to more than 100 bushels per acre. The increase from 1930 to 1940 (the period of most rapid adoption of hybrids) was almost solely the product of plant-breeding research.

Since 1940, plant-breeding progress has continued, but other factors have contributed to the dramatic improvements in yield. These have included such changes as the use of herbicides, increased fertilization and planting rates, more efficient planting and harvesting machinery permitting greater timeliness of all field operations, the switch from double-cross to single-cross hybrids, and the use of insecticides for corn rootworm and other insect control. (Single crosses are the first generation of a cross between two inbred lines. Double crosses are the first generation between two single crosses.)

Use of 2,4-D as a herbicide on corn was effective only against broadleaf weeds and when improperly applied could cause root lodging and stalk breakage. It was soon replaced by other material. Replacement with newer materials has been a continuing process. Increases in corn yield through weed control have resulted from reduced weed competition rather than any direct increase in yield potential.

The innovation having the greatest impact on productivity was the increased use of fertilizers, particularly nitrogen. The use of nitrogen increased rapidly from about 5 pounds per acre in 1945 to 130 pounds or more now.

Other changes accompanied nitrogen use. Planting rates gradually increased from about 14,000 plants per acre to between 22,000 and 24,000 plants per acre. In addition, new hybrids were being developed and grown. Experiments had shown sizable differences in responsiveness to added nitrogen. Those with limited response were replaced with types exhibiting greater response. A parallel situation was observed with planting densities. At increased planting rates, some hybrids showed more barrenness, thus reducing the response to added nitrogen.

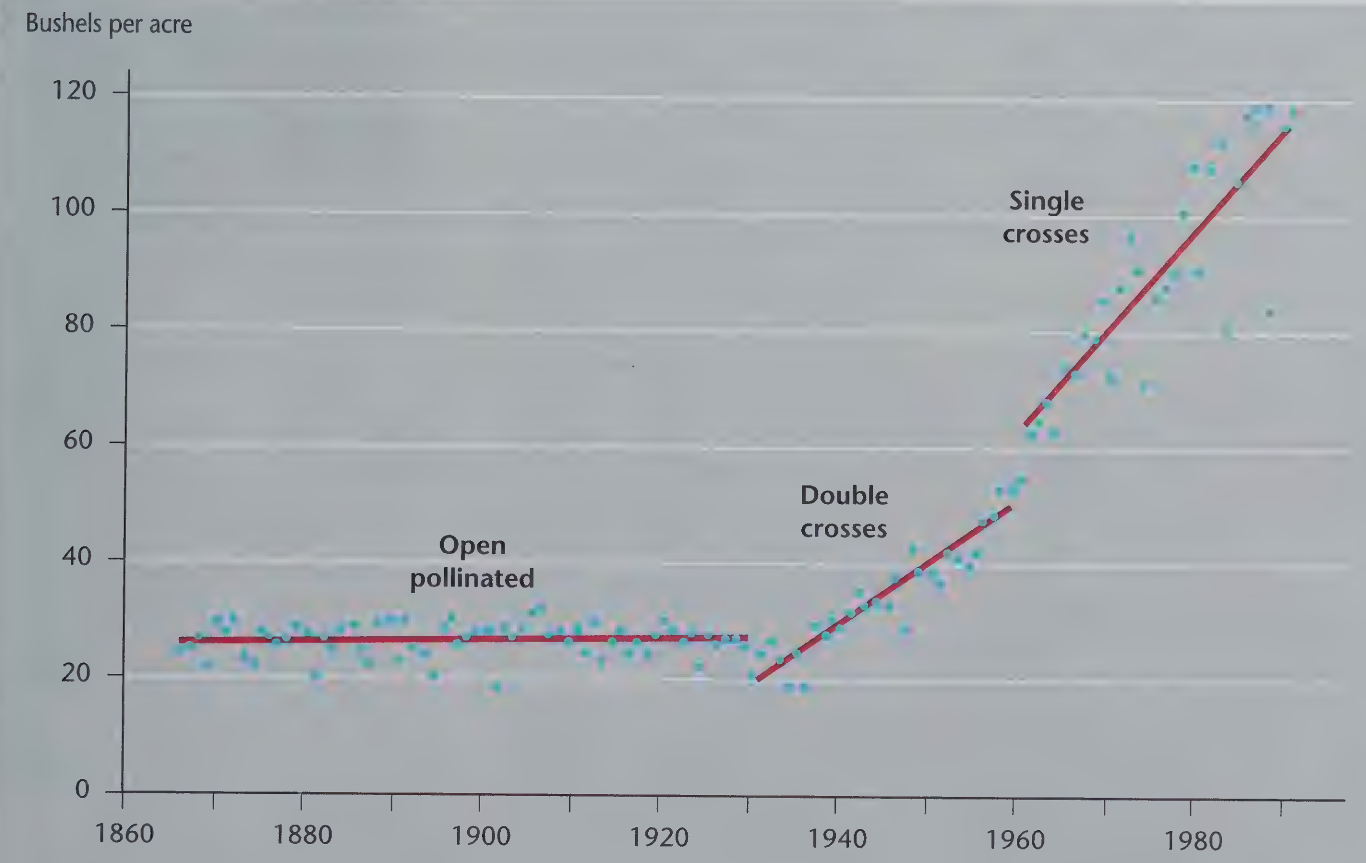


Figure 2. Average yields of corn in the United States: 1866–1990

Source: Forrest Troyer, DeKalb Genetics.

Warding Off Insects and Disease

A final change in hybrids began in the mid-1960s. Double crosses were replaced by single crosses as the hybrids of commerce. This change was made possible through the development of higher-yielding parental lines. Currently most commercial hybrids are single crosses.

The changes in yield per acre during the hybrid era, as depicted in Figure 2, were influenced partly by improved production practices. There have also been changes in disease and insect resistance, which are reflected in the yield pattern but less easily identified.

Leaf diseases and the stalk and ear rots represent the groups of diseases of greatest concern. Improvements through breeding differ among groups. Good sources of single-gene resistance have been found and used for most of the leaf blights. However, the pathogens are as genetically variable as the host. New races may arise from hybridization or mutation. By definition new races are identified by changes in patterns of infectivity. If a new race increases in prevalence to a point where it damages performance, then new sources of resistance must be sought and incorporated into the parent lines of current hybrids. Thus the search for new and better resistance must be continuous.

Any of several different genera may cause stalk and ear rots. No sources of single-gene resistance are known within this group. However, there are differences among corn strains to severity of attack. Selection for such differences has been practiced, and current hybrids are much less susceptible to lodging than hybrids of an earlier period.

No satisfactory level of resistance to the corn rootworm has yet been found, and crop rotation and insecticides remain the primary means of control.

What Is a Hybrid?

Through painstaking effort, early plant breeders discovered that when two different plants were crossed, their progeny sometimes performed better than either parent. This became known as "hybrid vigor." In the case of corn, it was discovered that crosses between individuals from different varieties sometimes showed a lot of hybrid vigor, and that much higher yields could be produced with such hybrids.

The first commercial hybrid seed corn was grown in Iowa in 1923, with the cross being "forced" by hand removal of the tassel (male flower) on the "seed" plants, such that pollen to fertilize the kernels on those plants had to come from the second variety grown in the same field. Even though this method of seed production was labor-intensive and yields of the seed parents were not always good, the use of hybrids spread rapidly in the 1930s and 1940s. Today virtually all corn produced in the United States is grown from hybrid seed.

Breeding efforts are directed toward improvement of populations (like the early varieties), from which are selected superior inbreds to serve as hybrid parents. *— Emerson D. Nafziger, associate professor of crop production and Extension, Department of Agronomy*

Breeding for insect resistance has received much less attention due in large part to the difficulty of developing effective screening techniques. Resistance to the first brood of the European corn borer has been found and is widely used. However, resistance to the first brood and resistance to the second brood are unrelated. Because of the corn borer's tremendous capacity for population expansion, a reduction in the first brood has little effect on the size of the second brood and its capacity for damage. Two inbred lines have been identified as possessing some second-brood resistance, but these are not used extensively. Thus, their field effectiveness is not firmly established. No satisfactory level of resistance to the corn rootworm has yet been found, and crop rotation and insecticides remain the primary means of control.

The information in Figure 2 indicates that the breeding methods used have been effective over a 60-year period, and there is no indication that their effectiveness is decreasing. However, current methods of evaluation are inefficient for many of the traits of major importance (for example, yield and lodging), and improved techniques are needed.

The genetic characteristics of any organism are largely controlled by the DNA carried by the chromosomes. Quantitative traits such as yield and lodging are difficult to manipulate because they are influenced by many genes whose individual effects are not easily identifiable. Genetic engineering offers hope for resolving this problem. The chromosomal DNA may be broken into small fragments through the use of special enzymes. The resulting fragments have been called restriction fragment length polymorphisms (RFLPs). From these a library has been developed and correlated with a standard gene map. Using these techniques, it should be possible to locate, follow, and measure the effects of individual genes. When such techniques become generally feasible, laboratory procedures may be used to accurately identify and manipulate individual genes.

Preliminary studies appear to hold promise, but the full potential must await further research.

G.F. Sprague, emeritus professor of plant breeding and genetics, Department of Agronomy ■

Converting Corn into Food and Industrial Products

Steven R. Eckhoff

Most corn grown in the United States each year is fed to animals. Nearly 80 percent of our domestically consumed corn is used as animal feed. But feed use is declining, as it has been for the past two decades. The fastest growing use of corn today is for food and industrial products.

About 20 percent of the annual corn crop is converted into food and chemicals, up from approximately 6 percent used for such purposes in the early 1960s. The growth in nonfeed uses has helped offset the decreasing demand for animal feed in an era of increasing corn production. As devastating as were the corn surpluses of the late 1970s and early 1980s, they would have been much worse without the increase in consumption resulting from this new trend.

Three main commercial processes are used to convert raw corn into food and industrial products: wet milling, dry milling, and alkali processing. To understand these processes, it helps to begin with an examination of the composition and structure of the corn kernel itself.

Kernel Close-Up

The corn kernel comprises four main parts: germ, pericarp, tip cap, and endosperm (see Figure 1). The germ is the only living part. It contains the essential genetic information, enzymes, vitamins, and minerals for the kernel to sprout into a new corn plant. Corn oil, comprising about 25 percent of the germ, is pound for pound the most valuable part of the corn kernel partly because of its relatively high level of linolenic fatty acid (a desired polyunsaturated fat) and its bland taste. The pericarp is the outer covering that protects the kernel from deterioration by resisting penetration of water and water vapor and by being undesirable to microorganisms and insects. The tip cap is the only area of the kernel not covered by the pericarp. It was the attachment point of the kernel to the corn cob and is the major path of entry into the kernel. During in-field drying, a black hilar layer forms in the tip cap region to partially block this pathway and thus protect the kernel. The endosperm, approximately 82 percent of the kernel's dry weight, is the source of energy and protein (in the form of starch) for the germinating seed. The thick-celled, highly proteinaceous aleurone layer on the outside of the endosperm acts as a semipermeable membrane to restrict the flow of gases and liquids into the endosperm.

There are two types of endosperm: soft and hard. In hard endosperm, starch granules are tightly packed together, each held firmly in a protein matrix. The starch granules in soft endosperm are held together more loosely. In most Midwestern hybrids, hard endosperm is located around the sides and back of the kernel, whereas soft endosperm is in the

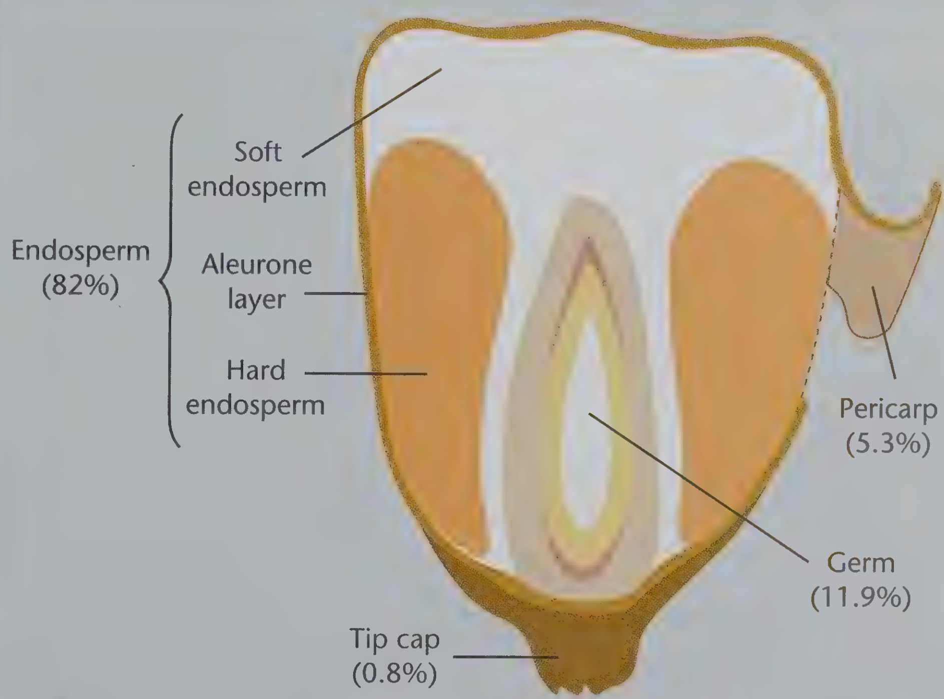
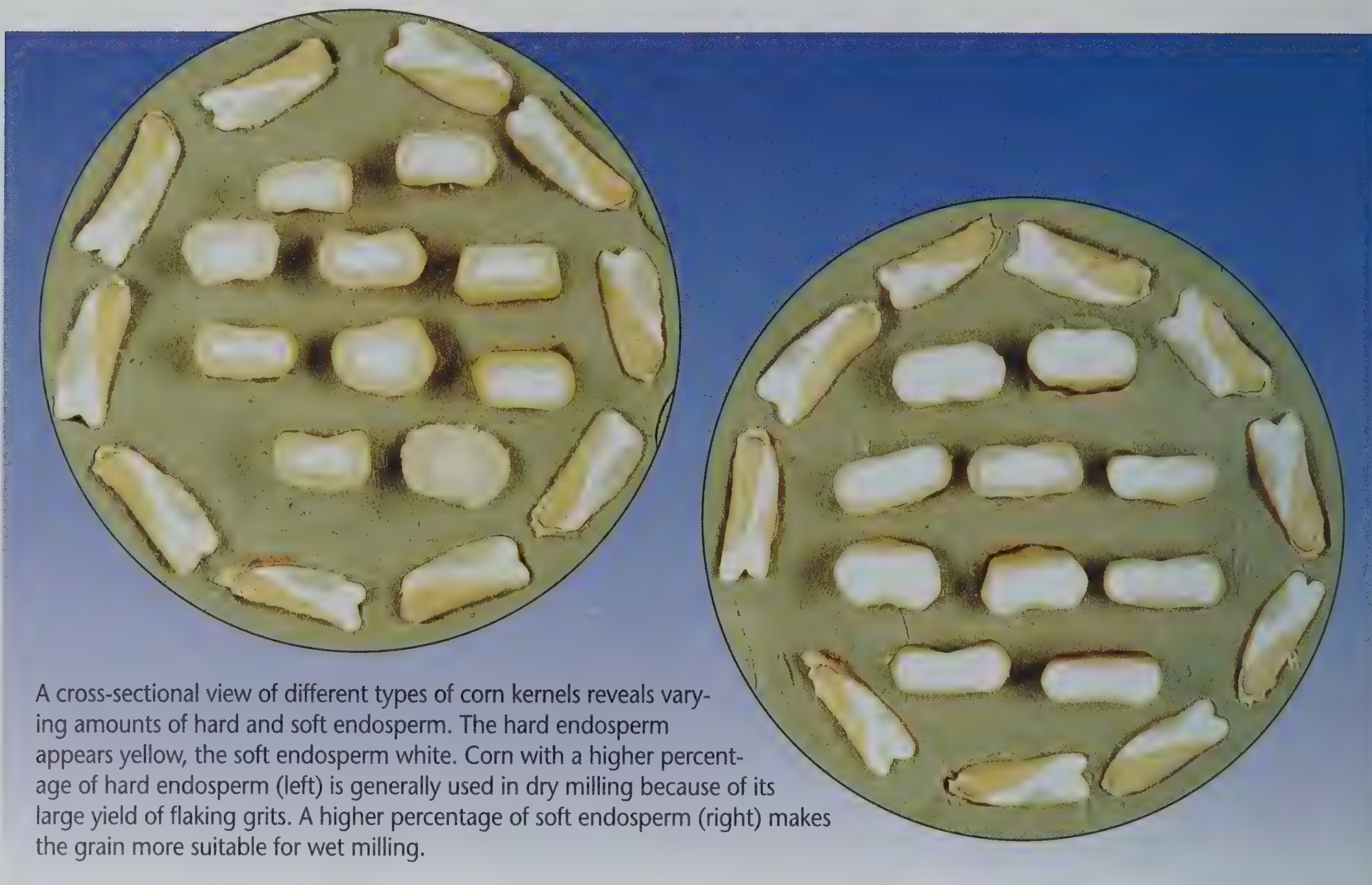


Figure 1. The corn kernel.

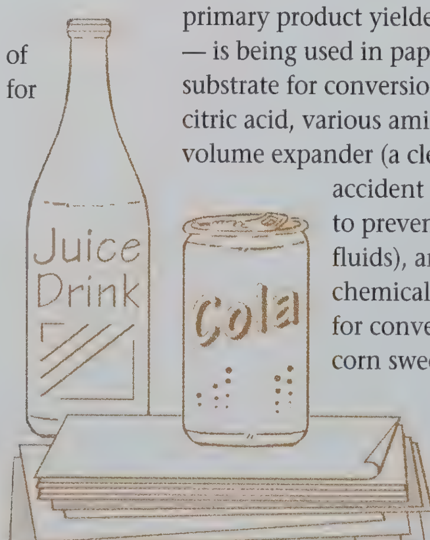


A cross-sectional view of different types of corn kernels reveals varying amounts of hard and soft endosperm. The hard endosperm appears yellow, the soft endosperm white. Corn with a higher percentage of hard endosperm (left) is generally used in dry milling because of its large yield of flaking grits. A higher percentage of soft endosperm (right) makes the grain more suitable for wet milling.

center and crown. During field drying prior to harvest, moisture loss causes the collapse of the soft endosperm structure and the formation of a dent in the crown of the kernel. As the hard endosperm dries, its protein matrix does not collapse.

Wet Milling: Cornstarch, High-Fructose Corn Syrup

Most of the growth in the use of corn during the last three decades has been in the area of wet milling, which accounts for 75 percent of all processed corn. The amount of wet-milled corn has grown from 155 million bushels in 1960 to more than 1.1 billion bushels in 1990. Four primary reasons explain this dramatic increase: the advent of high-fructose corn syrup, the continued growth in both the paper industry (which uses approximately 40 percent of all cornstarch produced) and the preprocessed food industry, and the resurgence of fuel ethanol.



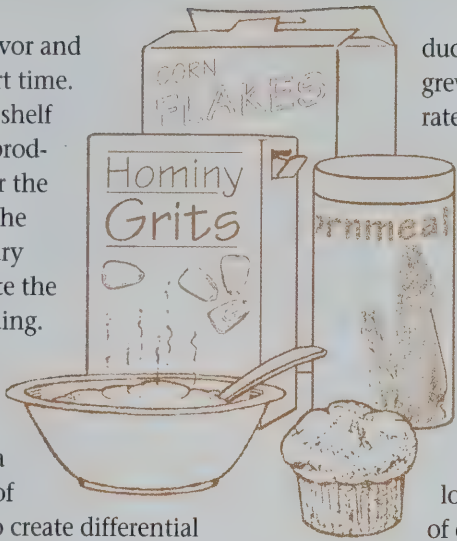
The objective of wet milling is to separate corn into its chemical constituents: starch, protein, fiber, and oil. It provides a much cleaner separation of the germ and pericarp than does dry milling. The intermediate products of starch, protein, and oil are suitable for conversion into a host of final products. Cornstarch — the primary product yielded by wet milling — is being used in paper products; as a substrate for conversion to ethanol, citric acid, various amino acids, blood volume expander (a clear liquid given to accident victims at the site to prevent critical loss of fluids), and other biochemical fermentations; for conversion into various corn sweetener products such as high-fructose corn syrup; and in the production of specialty starch products for use in food. The future of corn wet milling appears brighter with each discovery of new starch uses, including as a filler for biodegradable plastics and styrofoam, and as substrate for conversion into a fat substitute. (For a more detailed look at wet milling, see sidebar on page 22.)

Dry Milling: Grits, Meal, Flour

The dry-milling process is another way to break down the corn kernel into its components. The method aims to separate the kernel into endosperm, bran, and germ primarily through mechanical force. Whole-kernel grinding is a simple way to produce cornmeal or corn flour to be consumed as a cooked product such as cornbread, cornmeal mush, or hominy grits. Whole grinding is also used in many fuel or beverage ethanol plants to prepare the corn for cooking and fermentation. Meal and flour products produced by whole-kernel grinding have a limited shelf life because oil released from the ground germ can

produce rancid flavor and odor within a short time.

To increase the shelf life of dry-milled products and to recover the valuable oil from the germ, most large dry millers degerminate the corn prior to grinding. The dry corn is tempered by the addition of steam or water to a moisture content of 18 to 24 percent to create differential swelling among the germ, endosperm, and pericarp and to toughen the germ and pericarp so that they can withstand mechanical impacting without shattering. The tempered corn is sent to a degerminator that mechanically impacts the kernels to cause a separation between the components while maximizing the size of pieces in each fraction. The material from the degerminator is dried, aspirated to recover the pericarp, and passed over a gravity table to recover the germ. The remaining endosperm pieces are roller-milled and sieved to produce different-sized fractions.

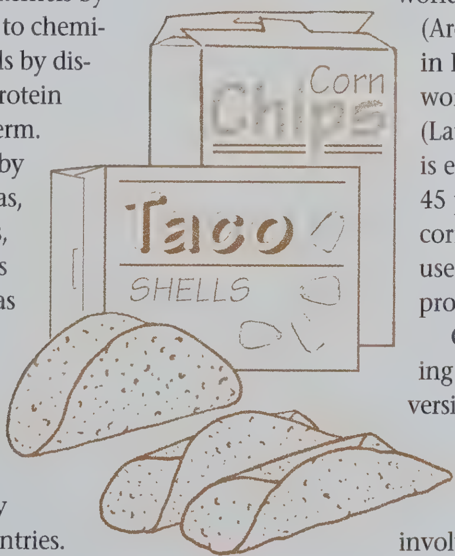


Endosperm products are classified into one of three categories, from coarse to fine: grits, meal, and flour. Dry-milled products in these categories can be further divided into more closely sized fractions for various commercial uses. The largest grits (flaking grits) are used to make cornflakes for breakfast cereals, whereas smaller grits are used in certain breakfast cereals, extruded maize snacks, and brewed alcoholic beverages. Cornmeal fractions are used in snack foods, food mixes, and brewing. Corn flour is used in many food mixes, food coatings, breadings, and in applications where the ability of wheat flour to rise is not required. Dry-milled corn is also used in a number of nonfood products, including plywood, gypsum board, biodegradable plastics and enzymes, and as a substrate in the fermentation of various biochemicals and intermediate chemicals.

In the past three decades, use of corn for dry milling (excluding ethanol production) in the United States grew at an average annual rate of only 1.5 percent per year (113 million bushels to 183 million bushels). The heterogeneity of the intermediate products limits their use in many final products. Future growth in dry milling may be a result of the lower capital cost and lower energy consumption of dry milling as compared to wet milling. Significant possibilities exist for using dry milling as preparation for further wet separation of the corn components. Worldwide dry milling of corn will grow at a faster pace than domestic use as people in developing countries acquire a taste for corn-based breakfast cereals and snack foods.

Alkali Processing: Tortillas

Alkali processing is the cooking and steeping of corn in a lime solution to physically soften the kernels by water absorption and to chemically soften the kernels by dissolving some of the protein matrix in the endosperm. Some products made by this process are tortillas, corn chips, taco shells, and tortilla chips. This processing method was developed by Native Latin Americans, and such products are still the major source of energy and nutrition in many Central American countries. Increased consumption of alkali-processed ethnic food and snack food in the United States is outpacing most other food uses of corn.



In alkali processing, corn is mixed with water and lime and cooked at 203°F for 50 minutes. The exact time and temperature of cooking depends on the type and quality of corn used and the products to result. Once the corn is cooked, it is steeped for 8 to 16 hours before being washed with fresh water to remove loosened pericarp and residual alkali. The corn is then milled to produce what is known as *masa*. This doughy substance is a result of the degradation of the protein matrix in the endosperm caused by the alkali. It is also gritty due to the incomplete degradation of the protein matrix in the hard endosperm. The masa can be rolled into flat cakes and quickly baked to produce the traditional tortilla or can be deep-fried to produce tortilla chips or corn chips. The masa can also be dried and finely milled to produce a flour that is sold as a mix for making tortilla products.

Illinois is home to the world's largest wet mill and the world's largest dry mill.

Corn processing is a vital part of the Illinois economy. The state has the world's largest wet mill (Archer Daniels Midland in Decatur) and the world's largest dry mill (Lauhoff in Danville). It is estimated that 35 to 45 percent of the Illinois corn crop ends up being used in one of the two processes.

Corn process engineering research at the University of Illinois focuses on developing a scientific understanding of the principles involved in current processing and in using this understanding to develop new and novel corn-processing procedures. This research will lead to the development of new products as well as greater efficiency and cost effectiveness in the industry.

Steven R. Eckhoff, associate professor, Department of Agricultural Engineering ■

How Wet Milling Works

Corn wet milling is a complex, energy- and capital-intensive process that accounts for three-quarters of all corn processing.

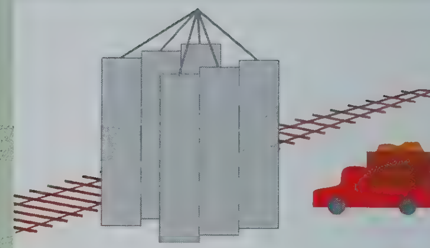
First the corn kernels are soaked 24 to 38 hours in a dilute sulfurous acid solution (sulfur dioxide and water) at 122° to 130°F. Steeping is performed in a continuous counter-current manner through large batteries of stainless steel tanks ranging in capacity from 5,000 to 15,000 bushels each. The diffusion of sulfur dioxide into the endosperm during steeping ultimately releases starch from the protein matrix. Approximately 7 percent of the total dry weight of the incoming corn is solubilized into the steep water, much of it coming from the germ, which is high in minerals, vitamins, soluble protein, and soluble sugars. The nutrient-rich steep water is evaporated and used as a nutrient source in biochemical fermentations or is added to the gluten feed fraction.

The steeped corn is lightly milled to tear at the toughened pericarp and allow the release of the swollen germ. The germ is recovered by cyclones that utilize the density difference between the oil-rich germ (now concentrated to more than 50 percent oil) and the remaining mash. A second milling is performed at a tighter setting to release any remaining attached germ. Approximately 7 percent of the dry weight of the corn is recovered in the germ fraction (containing 1.5 to 1.8 pounds of oil per bushel). Once the oil is extracted from the germ, the expended germ meal is sold as a 20 percent protein feed or is combined with the fiber fraction and steep water solids to form 21 percent protein gluten feed.

Once the germ is recovered, the remaining material is finely ground in a double-disk attrition mill. In modern wet-milling plants, one of these large attrition mills can require two 600-horsepower electric motors and can process more than 1,700 bushels per hour. The finely ground corn then passes through a series of bent screens to recover the pericarp and cellular fiber. This fiber fraction, which accounts for 9 to 15 percent of the initial corn dry weight, is dewatered, pressed, and dried. It constitutes the basic ingredient in corn gluten feed.

The material passing through the bent screens is a solution of starch and protein (often referred to as gluten). Separation of starch and protein is achieved by the use of continuous centrifuges that operate in a manner similar to a cream separator. The first centrifuge, called the mill stream thickener, dewaters the solution and sends the low solids containing water to the steeping operation for use as steep water. The concentrated solution is then sent to the "primary starch separator," where the overflow is rich in protein and the underflow rich in starch. The protein-rich fraction is further thickened in a centrifuge and dewatered using a continuous belt filter. The resulting protein cake, containing 50 to 60 percent moisture, is dried to produce a 60 percent protein feed product called gluten meal. Gluten meal is prized in the poultry industry for its high protein level and bright yellow color due to the large amount of xanthophyll pigment it contains. The xanthophyll pigment gives poultry a yellower skin color and eggs a yellower yolk.

The starch-rich fraction, containing approximately 3 to 5 percent protein at this point, is washed using 7 to 9 gallons of water per bushel in a series of microcyclones to separate the remaining protein from the starch. The resulting starch product, containing less than 0.35 percent protein, is then dried to produce pearl starch or is converted to specialty starches or other starch-based products. Normal industrial starch yields are approximately 67 percent of the initial dry weight of the corn kernel. — *Steven R. Eckhoff*


Receiving, storage, cleaning

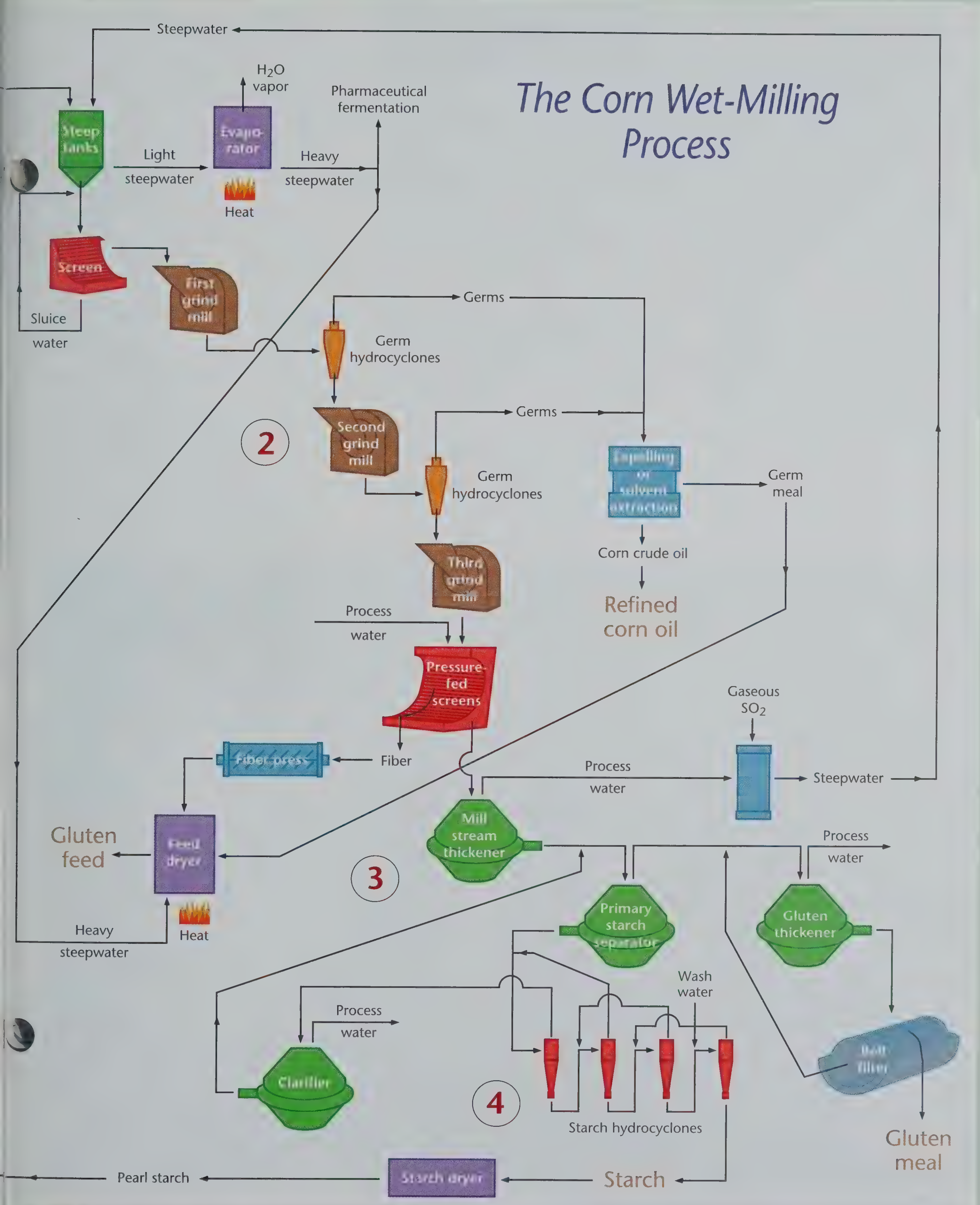
1

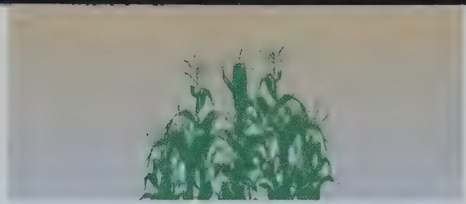
Main stages

1. Steeping and germ separation
2. Fiber washing and drying
3. Starch gluten separation
4. Starch washing

Starch products

- High-fructose corn syrup
- Paper products
- Industrial chemicals
- Ethanol


The Corn Wet-Milling Process
Steepwater
H_2O vapor
Pharmaceutical fermentation
Steep tanks
Light steepwater
Evapo-rator
Heavy steepwater
Heat
Screen
First grind mill
Sluice water
Germs
Germ hydrocyclones
Second grind mill
2
Germs
Germ hydrocyclones
Expelling or solvent extraction
Germ meal
Corn crude oil
Refined corn oil
Third grind mill
Process water
Pressure-fed screens
Gaseous SO_2
Fiber press
Fiber
Process water
Steepwater
Gluten feed
Feed dryer
Mill stream thickener
3
Process water
Heavy steepwater
Heat
Primary starch separator
Gluten thickener
Wash water
Process water
Clarifier
4
Starch hydrocyclones
Belt filter
Gluten meal
Pearl starch
Starch dryer
Starch



Why Illinois Is the Heart of Corn Country

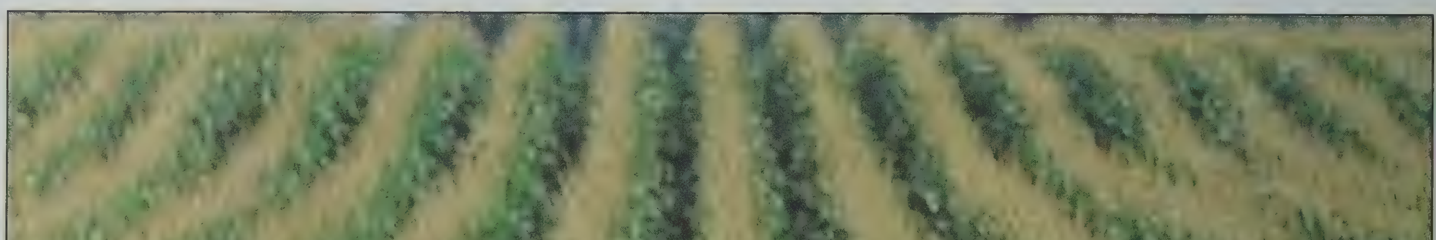
Emerson D. Nafziger

Illinois lies at the center of the legendary Corn Belt, which stretches across the nation from Ohio to Nebraska. This region is one of the most productive in the world. And Illinois, as the "Buckle on the Corn Belt," represents the best of the climate and soils that make it so.

Although most of the world's annual crops could grow quite well in Illinois, corn is the state's major crop and has been ever since the native prairie was broken. Corn acreage in Illinois reached 5 million by 1867 and 10 million by 1895. Acreage figures from around the turn of the century resemble those of modern times. In contrast, soybean production began only about 1910, and oat acreage peaked at nearly 5 million acres in the 1920s before dropping to less than a quarter of a million acres today.

History of Corn as a Crop

Archeological evidence indicates that corn was domesticated more than 7,000 years ago in parts of Central America. This domestication process was dramatic and ingenious. In most food crops, wild ancestors were simply selected over long periods of time to produce more and better-quality food. In the case of corn,



Illinois' rich soils and warm summertime temperatures are ideal for corn production.

evidence suggests that the domestication was so complete that not only could the crop not exist in the wild but also few if any wild relatives exist. From the center of origin, corn (known as maize in most of the world) spread to become the major food staple of most of the people living in the Americas in pre-Columbian times.

When Europeans first came to the Western Hemisphere, they thus found corn growing from the Caribbean islands to New England. There were considerable differences among the types of corn being produced, from flour corns with very soft starch in their kernels to the hard-kernel "flint" types. We all know the story of how Native American farmers showed the early New England immigrants how to raise a better crop of corn. Farther west, Great Plains and Eastern woodland dwellers also depended on this crop, the seed of which had likely reached the interior of North America by way of trade with people living in the Southwest, including modern-day Mexico. Corn was the staple of the Cahokia dweller in Illinois, and corn diseases may have contributed to the decline of that settlement.

The development of modern hybrids, which have made corn such a successful crop in Illinois, began with a genetic "accident" several hundred years ago. European settlers in the southeastern United States found growing there a type of corn that was quite different from the short-growing flint varieties common in the Northeast. The southeastern plants were taller, the ears were larger, and the kernels generally were dented on their outer end.

When the flint and dent types of corn were grown near one another, some of the resulting cross-pollinated plants possessed good traits from both sides. They were higher-yielding than the flints but had some of the flints' good kernel characteristics. Farmers of the Middle Atlantic region gradually kept these superior types.

As settlers moved west during the early 1800s, they carried these corn varieties with them to plant on the newly opened land. Fields where these varieties were grown contained numerous types of plants with variations in maturity, plant height, and kernel traits.

Some of the more innovative farmers noticed that if they kept ears from the better plants as seed, the next generation would retain some of those better characteristics. In this way, varieties became higher-yielding and more uniform. Some of these varieties became known for their originators; names like Reid's Yellow Dent designated a corn variety that had been selected for better field performance.

Around the turn of the century, plant scientists had confirmed some of the principles of genetics, and the science of plant breeding took on a firmer scientific base. Soon hybrid corn had been developed, and the use of hybrids spread rapidly. Today virtually all corn produced in the United States is grown from hybrid seed. (See "Development and Adoption of Hybrid Corn," page 15.)

Perfect Place for Corn

In 1991, about 69 million acres of corn were harvested for grain in the United States. Of that total, 11 million acres, or about 16 percent, were grown in Illinois.

The comparative advantage that Illinois enjoys with regard to corn production is clearly shown in Figure 1. Except for the dry years of 1980, 1983, 1988, and 1991, corn yields in this state have been well above U.S. averages. Even including the drought years, the corn yield per acre in Illinois has averaged some 6 percent above the U.S. average yield over the past 12 years. In the years when the weather has been favorable, yields in Illinois have been as much as 15 percent above the national average.

Although the importance of Illinois as a corn state is clearly illustrated in the production statistics, it is also instructive to look at the requirements of this crop and at the combination of soil and climatic factors that make corn so well suited to this state.

In spite of its subtropical origins, corn has been adapted to many different climates around the world and can be found from the lowland tropics to cool areas more than 7,000 feet above sea level. Still, this crop is rather sensitive to poor weather, especially drought.

The most common limiting factor to corn yield in Illinois is a shortage of

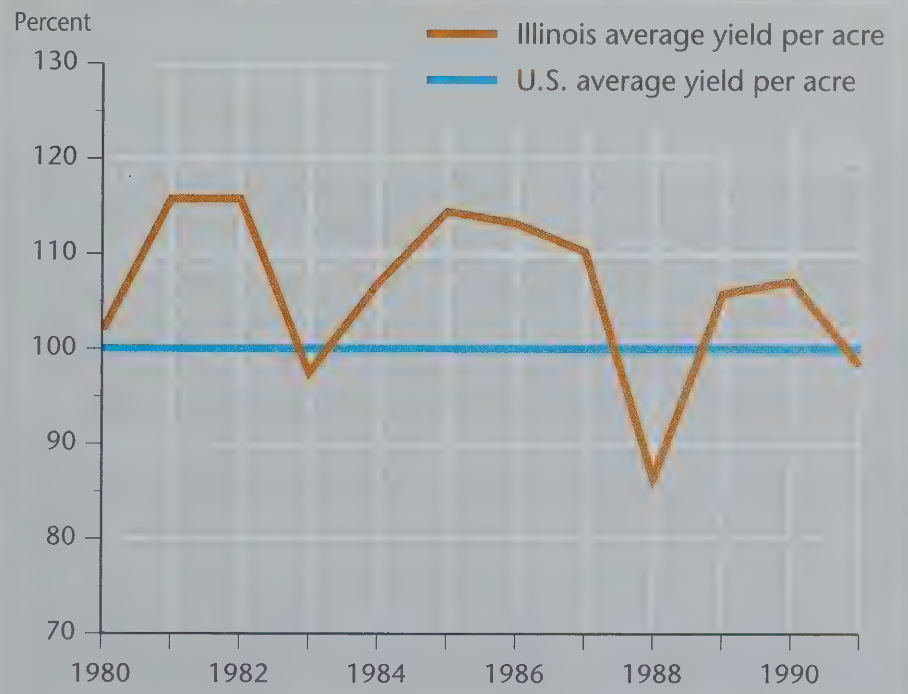


Figure 1. Illinois average corn yield per acre, as percentage of U.S. yield.

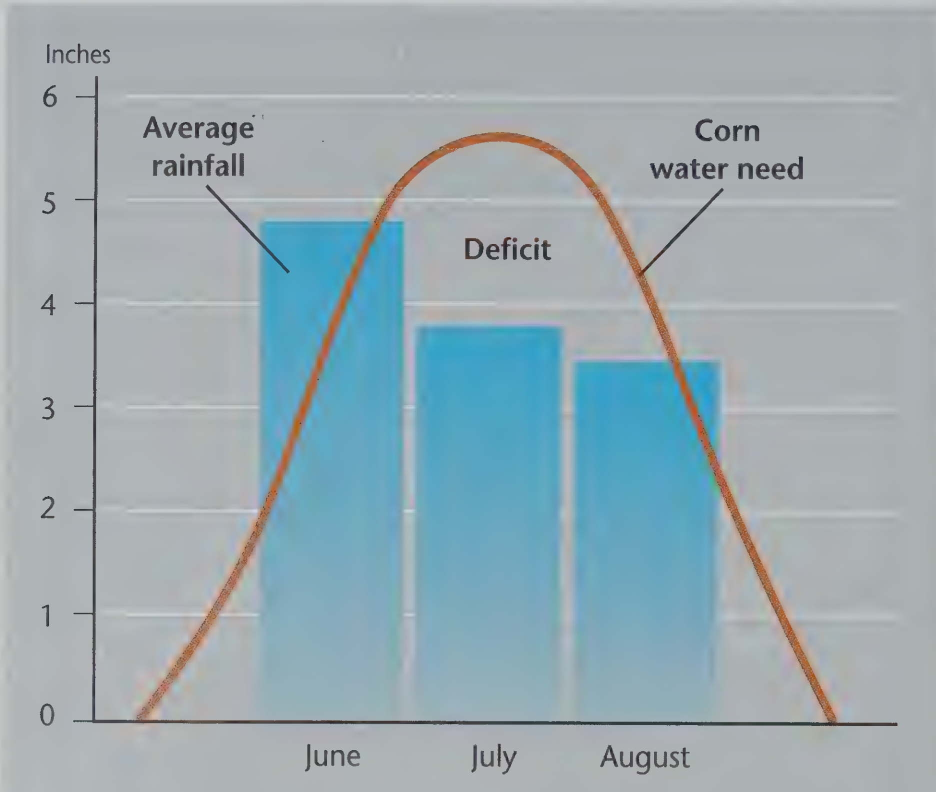


Figure 2. Average rainfall and corn water requirement in the Corn Belt. The deficit must be made up by water stored in the soil.

water. Corn requires about 22 inches of water to produce a high yield, though water use can vary from less than 18 inches to 25 inches, depending on the evaporative demand.

Corn is one of the more water-consumptive crops grown in Illinois. Most of the water is used from June through August, with peak use of as much as 0.3 inch per day during mid-July. The corn plant is most sensitive to drought during this period, which happens to be when the Midwest is most susceptible to drought. It is therefore critical that the crop be supplied with water during July.

In Illinois, average July rainfall is not sufficient to meet the needs of the corn crop (Figure 2). In dry years, the deficit between the crop requirement and rainfall amount may be as high as 4 inches for this month alone.

Such a rainfall deficit would normally spell disaster for the crop. So why does the state produce so much corn?

The answer lies in the soil.

Illinois' prairie soils, once regularly plowed under, can retain nearly half the required 22 inches of water necessary to produce a bumper corn crop.

Many Illinois soils can hold as much as 10 inches of plant-available water in the rooting zone because of their depth and excellent physical texture. It is this quality of our better soils that makes this state so well suited to corn production. In the deep silt loam or silty clay loam soils, enough water is stored in the rooting zone to provide up to half of the crop requirement for the entire growing season.

On sandy soils or on soils where root growth is restricted (such as compacted or poorly drained soils), the amount of available water may be much less, and short periods of drought may greatly decrease yield. Physical restrictions to root growth are common in some of the "claypan" soils of southern Illinois, and corn grown in these soils suffers drought when rainfall is low or poorly distributed.

In some areas in 1988, drought was so severe that the stored moisture in even the best soils was inadequate. Still, a drought as severe as the one in 1988 would have caused a total crop failure in most rainfed, corn-growing areas of the

Optimizing Nitrogen Use for Maximum Yields and Environmental Safety

Illinois corn growers routinely use nitrogen fertilizer because most soils lack enough plant-available nitrogen to support desired production levels. Each year, however, growers face the dilemma of accurately assessing how much fertilizer to use without jeopardizing the environment. The lack of a foolproof test for measuring nitrogen availability is complicated by limitations associated with nitrogen fertilizer application and by uncertainty related to weather conditions, especially water availability.

Nitrogen fertilizer recommendations are based on expected yield goals and, to a lesser extent, on formulas to estimate the soil's capacity to supply nitrogen (based on soil type, organic matter, previous crop, and amount of manure). Although generally sound, problems can arise if the expected yield is unrealistic or if growers fail to accurately assess soil nitrogen availability. The tendency to over- or underfertilize could be reduced if corn growers had a reliable method to rapidly assess plant nitrogen status while there was still time to correct deficiencies.

The need for a more reliable test has led to several new technologies to estimate plant-available nitrogen. The so-called late-spring nitrate test involves a home-test kit for determining the level of soil nitrate when corn plants are approximately 6 inches tall. Nitrate concentrations higher than 20 to 25 parts per million are considered adequate for maximum yield, whereas lower values would require additional fertilizer. Mounting evidence suggests, however, that this technique is most effective for identifying situations where no fertilizer nitrogen is required; it does not work well for predicting the degree of responsiveness to fertilizer applications. In addition, the nitrate test does not measure ammonium nitrogen, which under certain conditions can constitute a substantial fraction of the total available nitrogen. These problems, and the relative difficulty in performing the soil nitrate analysis, have led to an alternative technique to estimate soil nitrogen.

The latest technique employs a recently developed hand-held meter that can rapidly measure leaf chlorophyll levels. The values obtained can be used to estimate the availability of soil nitrogen because leaf chlorophyll is closely associated with plant nitrogen status. A distinct advantage of this approach is that it integrates the effects of nitrogen availability (regardless of source) and plant uptake into a single, rapidly obtained value. Additionally, because they are based on the plant rather than the soil, chlorophyll measurements are more likely to reflect the direct impact of nitrogen availability on plant performance.

The development of rapid, reliable tools for assessing plant nitrogen status will greatly improve the management of soil nitrogen. With such tools, growers will be able to continue to achieve maximum productivity while safeguarding the environment. — *Frederick E. Below, associate professor of plant physiology, Department of Agronomy*

Plant physiologist Fred Below measures leaf chlorophyll with a meter developed by Minolta Camera Company. The reading helps him estimate how much soil nitrogen is available to the plant.

Corn likes about the same temperatures as do humans.

world. The fact that it did not do so in Illinois is a testimony to the value of our soil resource.

Temperatures for corn production in Illinois tend to meet the ideal for this crop more than does the water supply. As a crop of subtropical origin, corn thrives on warm temperatures, but not on hot temperatures. The ideal daytime temperature is 85° to 90°F, whereas nighttime temperatures in the 60s are considered best. In other words, corn likes about the same temperatures as do humans.

Research has shown that corn does best when June temperatures are about normal, when July temperatures are well below normal, and when August temperatures are slightly above normal. Temperatures in the upper 90s may not harm corn directly but can cause some injury if accompanied by low soil moisture. Temperatures below about 50°F can also cause temporary harm to the corn plant, and serious loss of leaf function can occur if temperatures dip to the low 40s.

The third climatic element important to the corn crop is sunlight. In comparison to other crops, the corn plant converts sunlight to dry matter very efficiently, even though the efficiency of conversion is only a few percent. Corn thrives on bright sunlight, though the close association between bright sunlight and drought may obscure the advantages of more sunlight. If we could guarantee enough water to the crop, then more sunlight would probably produce higher yields in Illinois.

Challenges for Corn Management

The development of hybrid corn seed was the first in a number of technological advancements that helped move corn yields from rather static levels existing through the 1930s to dramatic increases in yield seen since then. Although genetic improvement has probably represented the largest factor in corn yield increases, the development and use of nitrogen fertilizer and herbicides have also contributed a great deal to the high yields of recent years. The flexibility provided by the ability to control weeds and to provide plant nutrients as needed has allowed farmers to continue to change their production practices in response to the need to lower input costs per bushel.

No longer confronted by the largest barriers to higher yields — low soil fertility, weeds, and genetics — farmers in Illinois are now facing weather as a common "most-limiting" factor. This has meant some wider year-to-year swings in yield despite management that continues to improve. There is evidence, however, that these swings have been dampened somewhat by the superior genetic capability of modern hybrids to produce under stress. Still, we must be prepared to live with weather-related variability in yields unless steps are taken to reduce the effects of unfavorable weather (through such methods as massive irrigation development).

Now that corn management is generally quite good, further improvements are being attained at the farm level primarily through a gradual process of individual producers "fine-tuning" their operations to fit their particular soils, markets, and personal goals. Tillage is gradually decreasing as farmers attempt to increase soil cover and decrease costs. Attempts are being made to more closely estimate crop needs and to apply fertilizer nutrients accordingly. The response of different hybrids to management practices such as nitrogen rate is under examination in an attempt to optimize economic return (see sidebar). Many farmers are looking for ways to reduce herbicides and other chemical inputs. Although the impetus for most of these changes is economic, concern about the environment is also a driving force.

While attempting to optimize the economics of corn production, one must realize that the crop is growing in a changeable environment. When managing in such a variable situation, there is always the danger of "overmanagement" in response to weather conditions that may not occur again for a number of years. Corn must be managed for average conditions, which in Illinois happen to be quite good. This means being cautious about adopting practices (in response to conditions such as drought) that may reduce yield if the weather is better the following year. By the same token, management decisions should not be made based on the weather always being good, in the hope of reaping large benefits. From the viewpoint of both economics and the environment, sound management precludes excessive optimism or pessimism.

The Future

Genetic and environmental challenges likely will continue to drive the primary changes in corn management in Illinois. Through improved genetics, increased plant populations resulting in even higher yields may be possible, or less chemicals may be needed to control pests. Genetic manipulation through biotechnology will enable some of these changes. Lower nitrogen rates may be possible, and corn plants capable of fixing their own nitrogen (converting it into usable form) could be developed. There may also be more emphasis on "paid-for" grain quality factors that the farmer can manage to increase returns.

With or without further improvements, corn will remain one of the true wonders of productivity among the world's grain crops. And although some Illinois residents may bemoan the "Great Corn Desert," the state will continue to be a perfect place to produce this magnificent crop.

Emerson D. Nafziger, associate professor of crop production and Extension, Department of Agronomy ■

High-Quality Feed Means High-Quality Food

Tina M. Prow

When animal nutritionist Robert Easter looks over a field of Illinois corn in the fall, he sees something more than tassel-topped, sun-dried stalks standing military-straight, row after row. In the golden kernels barely visible under the reddish brown silk threads and crackling-crisp husks hanging on each stalk, he sees energy.

Solar energy is captured in each kernel. Used as livestock feed, the kernels provide energy for cattle, swine, and poultry.

From livestock and poultry, humans get high-protein foods — lean meat, milk, and eggs — that help fill their energy needs. The National Corn Growers Association estimates 1 bushel of corn used for feed results in 5.6 pounds of retail beef, or 13 pounds of retail pork, or 19.6 pounds of chicken.

"Through corn, we have the potential to capture solar energy and the potential to do something with it," Easter said. "We use some corn to feed people, but man can't live by corn alone. Livestock play a valuable role in enhancing grain, turning a low-quality food into a high-quality food."

The quantity of corn used for domestic livestock and poultry feed is estimated somewhere between two-thirds and four-fifths of the nation's 7.5 billion-bushel crop. Illinois growers contribute about 1.3 billion bushels to the total corn crop.

Keeping It Close to Home

Roughly two-thirds of the state's crop is exported or used for industrial purposes. The rest is fed to domestic livestock, often on the very farms where the corn is harvested. In some instances, feed companies with investments in milling equipment have added livestock components to their businesses to ensure a market for their feed product.

"The Midwest's livestock industry is basically a 'grow your own' industry — farmers raise the corn, grind it, and feed it to their own livestock. Sometimes it's bought from neighbors, and larger pro-

An important ingredient in livestock feed formulas is corn, which provides energy cattle need for growth and weight gain.

ducers are specialized enough that they may not grow corn, but corn used for livestock feed in the state doesn't generally move more than 10 miles," Easter said.

"So, there's a link between corn and livestock here; it would be difficult to say today which industry drives the other."

Superior Energy Source

Besides being abundant in the Midwest, corn is a superior energy source compared with other common livestock feeds, such as wheat, barley, and sorghum. The most important nutritional components of the corn kernel are starch, protein, and oil.

Swine and poultry producers typically rely on corn to satisfy most of the animals' energy needs. These simple-stomach animals easily break down cornstarch to a sugar that fuels essential body functions and development of muscle and fat. Corn protein is broken down to amino acids used to construct skin, tissue, and muscle.

The end result of a corn-based diet is much the same for beef and dairy cattle, but the use of corn is a little different. A fermentation process in the rumen, the first chamber of a four-chamber stomach, allows these "ruminants" to use many feed sources for energy. Consequently, cattle diets often include other foods, such as pasture grasses, silage, and hay. When corn is fed, the primary benefit from corn energy is growth of bacteria, which are eventually digested as protein. For these ruminants, then, producers generally use corn as a concentrated form of energy for attaining growth or lactation.

Corn Gluten Feed and Other Byproducts

For every bushel of corn wet-milled for alcohol production, approximately 16 pounds of highly nutritious byproducts result. As alcohol production continues to increase in Illinois, there is a tremendous opportunity for the efficient utilization of these byproducts to enhance the agricultural economy.

Corn gluten feed (10 pounds' worth of the 16 pounds of byproducts) includes what remains after the germ, starch, and gluten have been removed from the corn plus the condensed steep water. The product typically contains about 21 percent crude protein, 10 percent crude fiber, 1 percent phosphorus, and 1.5 percent potassium. The feed is available in wet (40 to 44 percent dry matter) or dry (90 percent dry matter) forms. Approximately 80 percent of the dry gluten feed is pelleted and exported.

Corn gluten meal (2.5 pounds) contains the insoluble zein proteins of corn along with small amounts of starch and fiber. It is used primarily in poultry production because it is high in xanthophyll, the carotenoid pigment that gives egg yolks and poultry their golden yellow color.

Corn germ meal (3.5 pounds) includes what remains of the germ after the oil has been extracted. It is usually dried and sold as a protein source for swine and poultry.

Corn steep water is often dried back on the gluten feed or sold as condensed corn solubles. This product contains the water-soluble proteins, carbohydrates, minerals, and vitamins present in the grain. It is often used as a component of liquid supplements for cattle.

Room for Improvement

As good as corn is for livestock feed, it could be better. One way to improve corn is to improve nutritionally important components of the kernel. Scientists at the University of Illinois have several projects focused on increasing oil content and increasing and improving protein.

"By changing basic corn itself, it's possible to capture more energy in the same quantity of corn — for example, grow the same number of bushels of corn per acre, but each bushel having more oil," Easter said. "More oil equals more calories, or energy, per bushel — which means more livestock could be fed on 1 bushel of corn."

Like higher oil, higher protein could make corn a better animal feed. Corn has about 8 percent protein concentration, low considering researchers estimate a good-quality protein has 14 to 18 percent protein concentration. Increasing the quantity of protein is only part of the solution, however. Researchers also are striving to increase certain key amino acids of protein, such as lysine and tryptophan, to improve quality.

"The key role of corn in the livestock diet is calories," Easter said. "Corn with increased oil content and increased protein quantity and quality will be a better product and allow farmers to feed more efficiently."

Another route to better, more efficient corn for livestock feed is through development of products that enhance existing nutritional qualities of corn. One such product is an enzyme that releases phosphorus in corn. Corn has about 85 percent phosphorus that nonruminants cannot digest. Consequently, the phosphorus passes out of animals to the environment through manure. A digestible enzyme that makes phosphorus available would prevent that waste and also save producers the cost of a supplement.

Improving feeding strategies is important for reducing costs and preventing

More than 80 percent of the corn gluten feed produced in Illinois is exported primarily to the European Common Market. Depending on the outcome of the current GATT negotiations, this product could lose its tariff-free status in the Common Market. Consequently, if more is marketed domestically, much of it will be sold wet to eliminate drying costs. This means that most will be sold within 200 miles of the production site. To show the impact this could have on Illinois agriculture, if all the corn gluten feed produced in Illinois were marketed here, the number of cattle required to consume it would be more than double what is now being fed in the state.

The Department of Animal Sciences has conducted eight research trials evaluating wet and dry corn gluten feed for beef cattle. In all cases, the feeding value of wet gluten was equal to or superior to dry gluten feed. The energy value of wet gluten feed is from 92 to 100 percent of corn, on an equal dry matter basis, depending on the forage level of the diet. The protein value for beef cattle is similar to soybean meal on an equal protein basis. In addition, wet corn gluten is very palatable and helpful in starting cattle to eat again after being shipped. Similar results have been obtained when used in the diets of dairy cattle or sheep.
— Larry L. Berger, professor, Department of Animal Sciences

Corn alcohol byproducts manufacturing is more than just a chicken feed industry in Illinois.

waste. Most farmers custom-blend corn both with supplements that provide calcium, phosphorus, trace elements, and vitamins and with soybean meals to match formulas researchers have developed to meet specific nutritional needs. Swine, for instance, usually are fed different feed formulas at three different growth stages. Researchers are looking more closely at that strategy to determine whether there should be even more stages and feed formulas.

"Technology has removed many limitations on the farm. Computer-controlled, automated mixing equipment makes it possible to feed more precisely so that animals get what they need — no more and no less," Easter said.

Change Continues

Feed formulas, or rations, for livestock and poultry have changed over the years, in part because researchers continue to discover more about animals' nutritional needs and about corn itself, and in part because consumer taste in meat changes. For instance, studies show consumers prefer grain-fed beef cuts when given a choice between grain-fed and pasture-grazed steaks and prime rib. Consequently, corn is often a component of livestock rations. At the same time, however, consumers also are demanding more lean and less fat. As a result, cattle are fed grain for a shorter period of time today than a decade ago in order to limit fat production. And feed formulas have been adjusted so that pork loin, formerly 7 to 8 percent fat, now weighs in at 4 percent fat.

But no matter how livestock feed formulas change, corn is likely to remain the primary ingredient.

"I don't see any potential for something else to come along and compete in our part of the world. There may be new or different supplements," Easter said, "but it looks like the corn and livestock combination is here to stay in the Midwest."

Tina M. Prow, science writer, Agricultural Experiment Station ■

In Progress

Research Key to Corn Producers' Future

Corn research will mean survival for producers in the years ahead. Research is needed to improve production efficiency for corn-based products such as ethanol, to bring products like the road deicer calcium magnesium acetate to market, and to develop corn products yet unknown.

In the 1970s, knowing how to grow corn efficiently was enough. In the 1980s, marketing corn effectively took center stage. Although both issues will continue to be critical, the 1990s needs to be the decade of research.

The task will not be easy. Developing ideas for research and then packaging and promoting the results of that research so it is picked up by industry represents a challenge. But it is a challenge that must be tackled.

The Illinois Corn Marketing Board (ICMB) has become increasingly sophisticated in its approach to generating quality research projects and promoting the innovative ideas to industry, government, and consumers.

Central to the goals of research development and promotion is the efficient use of corn checkoff dollars invested by producers. ICMB has evolved from strictly a funding agency into a facilitator that invests time and energy to make the most of the checkoff money.

An ongoing ethanol project between the University of Illinois and Pekin Energy Company provides the perfect example of how this philosophy works. The project began with the Illinois Corn Growers Association arranging a meeting among UI researchers, Pekin Energy, the Illinois Department of Energy and Natural Resources (ENR), and an engineering firm. The group explored ways Pekin Energy might become more efficient throughout the different phases of ethanol production; it revealed the one area with the greatest potential — so-called saccharification, a method used to convert cornstarch to glucose (which is then fermented into ethanol). The project was then submitted to ICMB, which gave it a priority ranking and offered \$36,000 seed money to the project to capture outside investment. The group effort triggered additional funding from UI, Pekin Energy, ENR, and the Great Lakes Governor's Council.

During the first year of the two-year project, the needed technology will be developed in UI laboratories; during the second year, the new technology will be installed and put to use in the Pekin Energy plant.

The cooperative effort will result in increased ethanol production to meet the growing demand for this clean-air fuel, proof that bench-scale technology can move rapidly to the commercial level, and in magnification of corn producers' checkoff investment. *— John C. "Jack" Fisher, executive director, Illinois Corn Marketing Board*

High-Oil Corn Project

High-oil corn seemed like a good idea to University of Illinois plant breeders in 1896 and began to look promising when D.E. Alexander selected for the trait in 1956. By 1972, the UI breeder was growing a high-oil hybrid for animal studies. The higher oil and protein made for a superior livestock feed. Still, industry showed little interest in the new corn.

Then in 1988, seeing potential for high-oil corn in their value-added foods and feeds programs, E.I. du Pont de Nemours and Company and Pfister Hybrid Corn Company negotiated for exclusive access to the university's high-oil germplasm stocks. UI retained ownership of the original materials and will receive royalties from hybrid seed sales. In addition, Du Pont awarded the university a three-year research grant, extended later to five years.

Exclusive agreements for university germplasm are rare. But according to John Goss, research supervisor with Du Pont's Agricultural Products, biotechnology group, the companies needed to protect their investment to commercialize high-oil corn products and concluded that protection through future patent rights would be unlikely because of previous publications on the research.

"The agreements meant a little more security in a venture that holds much risk and cost for us," Goss said. The

companies projected a 6- to 7-year investment of time and resources to develop commercial-quality hybrids from the germplasm stocks. They expected to campaign for a market niche. To preserve grain hybrid identity from the farm to the end user, they anticipated developing a special production system.

For the university, the agreements meant additional funding for research, which includes training students in plant breeding. Also, the collaboration improved the odds that the type of corn UI researchers envisioned nearly a century ago will reach the marketplace.

"I believe that relationships between industry and a university can be profitable in many different ways for all the parties," Goss said. "In the near term, it's being able to exploit the immediate invention through commercialization to generate revenues and royalties.

"But the research component of the agreement is something that has less tangible and more long-term benefits. I think it will benefit the university, scientific community, and farmers beyond the specific objectives of the commercial activities between Du Pont, Pfister, and the University of Illinois." — *Tina M. Prow, science writer, Agricultural Experiment Station*

U.S., China Work Together to Improve Soybeans

A small delegation of U.S. farmers and scientists has sown the seed for a major cooperative effort with China that may lead to improved soybean varieties for U.S. agriculture.

In June 1991, the U.S. delegation trekked to mainland China seeking access to Chinese soybean germplasm for U.S. researchers. Making up the delegation were Illinois farmers Lloyd Anderson and Ken Birkey; Iowa farmers Don Latham and Dave Stone; Donald Holt, director of the Illinois Agricultural Experiment Station; and Harold Kauffman, director of the International Soybean Program at the University of Illinois.

Less than a year after the trip, the delegation reaped the first fruits of its labor. In May 1992, Chinese scientist Chen Yi Wu came to Illinois, bringing with him 500 new soybean varieties for the National Soybean Germplasm Collection. The collection is maintained by the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS) at the University of Illinois at Urbana-Champaign.

The new varieties add genetic diversity to the Soybean Germplasm Collection, the nation's major soybean seed repository. The varieties come from central China, where soybeans originated; the Chinese have been raising soybeans as a crop for 3,000 years.

Randall Nelson, USDA scientist and curator of the Soybean Germplasm Collection, says that germplasm can be defined as the total genetic diversity of a species. "Continued increases in food production require improved varieties, and all plant improvement is dependent upon genetic diversity," he says. If the accord goes as planned, U.S. plant breeders soon will be able to receive samples of the Chinese seed for experimentation that might eventually result in improved traits of domestic varieties, such as resistance to insects and disease and higher protein content.

In return for the new germplasm, Chen will spend a year working with Nelson at the University of Illinois. During his stay, Chen will catch up on advances in agricultural technology not available at the Academy of Agricultural Sciences in Beijing, where he works.

The Chinese researcher will focus his efforts on learning techniques for efficient operation of germplasm facilities. He will also observe how Chinese seed stock performs in the Midwest. When he returns home, Chen will take with him not only a better understanding of U.S. agricultural technology but also some much-needed analytical equipment.

Two details of the accord yet to be completely ironed out relate to future access to the expansive Chinese germplasm collection in Beijing and intellectual property rights. "Although the Chinese have an excellent storage facility provided by the Rockefeller Foundation, they are unable to provide enough operating support to maintain, expand, evaluate, or enhance the collection adequately," says Holt. He explains that this problem may be overcome by the Chinese government's charging modest user fees to those requesting samples from its collection.

Holt says that China also wants to protect its intellectual property rights. "The Chinese government is not sure that giving the germplasm to other nations is the best way to manage such a valuable resource," he states. Licensing agreements providing for royalties or other payments for commercialized products derived from the germplasm may be one way to compensate China for use of its soybeans, he says.

Support for the cooperative effort comes from not only the USDA Agricultural Research Service and Illinois AES but also the Iowa Agricultural Experiment Station, the Illinois Soybean Program Operating Board, and the Iowa Soybean Promotion Board. —*Nancy A. Nichols*

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Illinois Research

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Revitalizing Rural Illinois

Illinois Research

Agricultural Experiment Station
Fall 1992

Revitalizing Rural Illinois

Preserving a way of life

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 34, Number 3

THE COVER

They're still to be found across America, rural towns that speak of the good old days and capture the hearts and minds of millions of city dwellers. Though many of these small towns have seen hard times, there are signs of economic, social, and political reforms that may help them make a comeback. We hope you'll take a moment to sit a spell with this issue of *Illinois Research* and examine the forces that have shaped and now challenge rural Illinois.

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Revitalizing Rural Illinois

Paradise Lost?

In spite of living in Oklahoma, studying and working in Australia and New Zealand, and living in a medium-sized college town, my roots and my heart remain in rural Illinois. I grew up on a farm just north of Carlinville, in Macoupin County, during the period immediately following World War. II At that time, farms were typically 160 to 240 acres in size. Each one-mile-square section of land provided work and home to three families, and a six-mile-square township could easily contain over a hundred families.

Our social life revolved around church, school, and neighbors. All families with children attending the one-room school (grades 1 through 3 at Chisholm and grades 4 through 6 at Laurel Hill) were members of the "community club." Neighbors were quick to support one another, particularly during the life events that made us vulnerable: birth, death, sickness, and injury. Church, school, reunions, and neighborhood gatherings, coupled with the freedom and hard work of farm life, wove the fabric of my childhood.

We described our farm and those of our neighbors as general livestock farms. Crop rotations included small grains and hay. Our small beef herd and sheep flock were pastured along the stretch of the Hurricane Creek that meandered our farm. A laying flock, a small swine enterprise, and two milk cows added to the work and income. With row crops, small grains, and forages being grown, we needed a full complement of machinery, although some specialized machinery was jointly owned and borrowing was common.

The farm life of my childhood was a somewhat isolated and private one. Although the neighbors were nearby and we could count on their support, work and play were largely our own. My brothers and I could often be found building tunnels and forts in the hay mow or fishing and hunting along the creek. The lawn mower was useful in marking base paths in the pasture for a neighborhood softball game. From our livestock, garden, and orchard we produced and processed nearly all our own food. We constructed our own buildings, and my mother made many of our clothes. I always knew that my life was quite different from that of children growing up in the county seat only four miles away. Today my nephews on the farm attend school in Carlinville, and there is little difference between their interests and activities and those of their town friends.

Over the years, hedgerows and fences were gradually removed to make farming with larger machinery more convenient. The livestock enterprises have fallen away until only the laying flock and animals for the freezer remain. A corn-soybean rotation predominates and, because my brother is a no-till innovator, the machinery complement has been greatly simplified.

Farms today are much larger. Within one-half mile of the house where I was reared with four brothers and a sister, three farmsteads have disappeared. A six-mile-square township can now be expected to support perhaps thirty families, with only half of those earning the majority of family income on the farm. Fewer farm families translates to less demand for local goods and services in rural communities. Larger farms, while more efficient by many measures, are also more apt to buy and sell direct, bypassing local businesses in the process. Rural communities that are similarly dependent on farming to support the local economy face an uncertain future.

Specialization has become a feature of rural Illinois. Many of the processes formerly done on farms and in homes, even food preparation, have moved into the business community. With more inputs and services purchased there, the result is greater interdependence between all parts of the food indus-

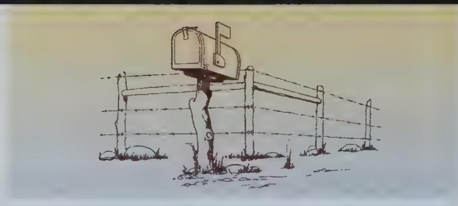
try — a fact that is not well recognized and appreciated by consumers and farmers alike. Our understanding of how public and private actions each profoundly affect the other also appears inadequate, but helps explain the growing public interest in how agriculture is practiced. Specialization and no-till technology appear to have us poised for another rapid increase in farm size. Less than two percent of us now live on farms — how soon only one percent?

During my childhood, work was located close to home for most rural residents, and most were self-employed. Today, the workplace is far removed from home for many modern rural citizens, including members of farm families who work off-farm. And most rural residents work for someone else. Many commute across community and county boundaries for child care and employment, often to regional centers. The allegiance to place and community has been altered, along with the sense of belonging. The fabric of rural social life is more loosely woven. Friends and neighbors are no longer one and the same, as they were when I was a boy.

It would be easy for me to be nostalgic for the good old days. I recall that not everything was terribly good. Yet I wonder at the pace and magnitude of these changes and the extent to which rural Illinoisans are able to control or even adapt to them. Clearly they can only be empowered by a common vision and collective action. Life has greatly expanded my concept of place and community.

This issue of *Illinois Research* is dedicated to fostering a greater understanding of the economic, social, political, and aesthetic features that continue to shape rural Illinois. I hope you will find it speaking to your roots and heart as it does to mine. — *Peter Bloome, assistant director and state leader of agricultural and environmental programs, Cooperative Extension Service*


Peter Bloome



The Lore and Reality of Small Towns

Andrew J. Sofranko

Something about small towns evokes such sentimentality that millions of city people routinely report their desire to live in one. Those living in a village or small town register high levels of residential and general life satisfaction in surveys. Perhaps it is their smallness, uniqueness, or stability — or that they were once hometowns for millions of Americans now older. Did they truly represent a way of life qualitatively better than that found in more modern suburbs and larger cities? Or is this longing nothing more than a vague nostalgia for the good old days?

Notwithstanding the sentiment attached to small communities, historically these were the places people came from, not went to. The qualities these places possessed weren't sufficient to hold those born and reared in them, or to attract many of those who still will swear by small-town virtues and values. Whatever strengths these people may have seen in small towns, it wasn't opportunity. In this respect, this trend is symptomatic of what is occurring across rural America. Population decline is as pervasive now as it has been at any time since the mid-1940s. Feelings toward small towns and their inability to capture either people or economic activity are spurring some serious debates about their future, as well as the future of rural areas.

The Idealist Vision

For many people, the traditional small town has captivated their hearts and minds as a true harmonious community, where people had close contact with helpful neighbors who were naturally inclined toward cooperation. People "looked in" on one another — you knew your neighbors, and they knew you. These communities were fairly homogeneous, made up of like-minded people. The most important institutions and basic living activities were contained within the community: shopping and employment, churches, recreation, schools, banks, post offices, and a small, responsive local government. There was a "functional completeness," as Richard Lingeman has pointed out in *Small Town America*. The boundaries of local institutions coincided with community boundaries, and communities were, at least in the minds of residents, insulated from the problems of the larger society. Any problems that existed were taken care of locally. Virtue resided in villages and small towns, as Lapham has pointed out. In the words of David Pichaske, editor of *Late Harvest,* these were places of "sanity and stability." But most of all, people were neighborly, decent, free of city vices, hardworking, honest, and unpretentious. The motto of Lake Wobegon, Garrison Keillor's fictional town, is, appropriately, "We are what we are."

The Realist Vision

The small town was not without its detractors, who pointed out that these were idealized communities with qualities glorified in literature by writers who had left the very places they praised. Few if any towns ever resembled this romantic version. In many cases they were the antithesis, which was pointed out by the American realists, a school of writers who attempted to lay bare the myth of the happy village by exposing the many negative facets of small town life. Lingeman writes of "conformity, suspicion of strangers and new ideas, the informal personal politics, the avoidance of divisive issues, the reliance on accommodation, the 'neighborliness' accompanied by a proclivity to pry into the private lives of their neighbors, and sporadic outbursts of populist opposition to centralized authority, whether government or economic."

These writers have variously described small towns as centers of hypocrisy, possessed with a smallness of vision. Pichaske describes them as a "tomb of dreams," rife with social, spiritual, and moral decay, repressive, and characterized by endless gossip and petty talk of "corn and broken marriages." They were the towns the "bright ones leave," and "before the village virus proves fatal." Characters in this genre of American literature describe small-town life as "pretty deadly" and "narrow," as if residents were living in a "cultural wasteland." Many of these negative images were as much a literary creation of small-town America as was the view propounded by its romantic boosters.

Small-Town Diversity

No midwestern small town was typical. Each emerged from divergent cultural streams, some as different as night and day. In Illinois, five major migration streams contributed to the considerable diversity in small towns. Southerners mi-

The Midwest leads the nation in the number of small communities — almost 6,000; 900 of them are found in Illinois.

grating across the Appalachians into the lower third of the state brought a different social and political culture and set of institutions than the more communalistic northerners who originated in the New England and Middle Atlantic regions. As James Madison explains in his book, *The Heartland,* overlying these migration patterns was an influx of blacks out of the Mississippi Delta and of ethnic groups directly from Europe. Some migrants and immigrants settled in relatively homogeneous ethnic communities; others blended in with the existing population. Many of the communities had a distinctive tie to agriculture and the land, while others were oriented primarily to transportation as river towns or railroad towns. Some were founded as mill communities or coal towns; others originated as speculative ventures that never succeeded and vanished from the map. Many ultimately became large towns and cities.

Small-Town Blues

The character of small towns is being eroded from within and without. The trains don't stop in them anymore, young people are moving out, and many communities are fighting to stay on the map, all of which adds up to what *Time* magazine in 1989 aptly referred to as "small-town blues." Consider this description, from a recent issue of *The Economist,* of present conditions in small towns on the western fringe of the Midwest: "Drive through them today, and you feel you are seeing these towns much as they were then. But for one thing: many are silent and deserted. Dust blows down Main Street. Half of the shop fronts are boarded up. 'Closed' signs hang on the other half. The bank has gone. The only sign of life is the occasional battered truck, steered by an old man often passing at the crossroads. Nearby, farmhouses and barns lean, empty, at precarious angles." The farm crisis of the early 1980s didn't help, nor have crop prices or federal subsidies done much to reverse the trends. The decline in lower-skilled manufacturing employment and the loss of jobs to other regions and countries have diminished the attractiveness of rural communities as industrial sites. The main source of income in many places is transfer payments, interest and dividends. When the young leave, an older, poorer population is left behind, with a poverty level not much lower than that of central city areas.

This description is not entirely accurate, for many small towns are doing quite well by any social and economic standard. However, one thing is certain — the nature of the relationship between residents and their communities has changed. The ease of commuting and the highway system allow people to work as well as shop outside of the community. Consequently, the level of popular participation in, and identification with, communities has declined. People simply don't spend much time in them.

At the same time, modern society has penetrated into once remote and isolated rural areas by way of cable and branches of urban-based businesses that bring services within the reach of many rural people. Franchise establishments provide the same range of choices to rural as to urban people. Government regulations have affected rural areas as well as urban. The gap that once separated rural and urban areas has narrowed considerably. The sum of these changes has produced what is often referred to as a loss of community or loss of a sense of place.

Small Towns and the Land

Small, rural communities are liberally scattered across the midwestern landscape. As a region, the Midwest leads the nation with almost 6,000 such communities. Illinois has close to 900, ranking next to Texas in the number of such communities. Many sprang up from a grass-roots desire to keep government small and more responsive to the public and to maintain homogeneity and a feeling of "community" among their residents. The formation of a new town was one way of ensuring both smallness and "community."

Whatever their origins, a common thread unified most rural midwestern and Illinois small towns — their intimate relationship to agriculture and the land. Rural communities served the hundreds of thousands of farmers and their families scattered across the state. When Illinois agriculture was made up of nearly a quarter of a million small family farms, and transportation was difficult, there was a need for a small town every 10 or 15 miles. It was also inevitable that the life of a community would be closely meshed with its ability to meet the needs of farm families. Today, if they still exist, rural communities that are tied exclusively to agriculture are relics. Twice as many farms have disappeared as now exist, and the functions of small rural communities have changed as a result of agricultural

trends and increased physical and social mobility, better transportation, and employment in nonagricultural jobs.

Discussions of rural communities often obscure the fact that over the years many of them have grown into small cities and larger urban towns. Just a few decades ago, Bolingbrook and Schaumburg were rural communities. The number of rural communities fluctuates slightly from decade to decade because of the incorporation of formerly unincorporated settlements, the creation of new rural communities, and the shift of communities from urban to rural and vice versa (see list illustrating these latter two shifts, 1980–1990). Twenty-two formerly rural communities are no longer defined as rural by the Census Bureau. Another eight became "rural" as a result of population loss between 1980 and 1990.

The 1990 Census reveals a dramatic decline in the number of rural communities that are growing in Illinois (Figure 1). This is in stark contrast to the 1970s, when nearly three of four small communities grew and even to the preceding decades when rural areas were being depopulated. The majority (56 percent) of those growing during the 1980s were in metropolitan areas of the state, especially in the northeastern portion.

One major consequence of this population loss in rural communities is aging of the remaining population. At a time when 12.5 percent of the state's population is 65 and over, it is not unusual to find rural communities with proportions ranging from 40 to 60 percent. In many of the more rural counties, median ages 5 to 7 years higher than the state average (32.8 years) are not uncommon.

Several factors are credited with contributing to growth. First is proximity to larger urban centers — small communities can "borrow" some of the advantages or amenities associated with urban living if they are located near a larger town. A second factor is access to good transportation. This permits people to travel out of town for jobs and many of the goods and services they desire but cannot obtain in a rural community. Good transportation also serves as an inducement to firms creating new jobs in rural areas. Finally, it is argued that some communities grow because they have a more dynamic and progressive leadership that encourages growth and improvement in community life. It's impossible to determine if differences in leadership, which undoubtedly exist, have had an effect on community growth and decline over the years. It's one of those things that is hard to measure.

Community Changes, 1980–1990

From Rural to Urban	1980	1990
Deer Park (Lake)	1,368	2,887
Hawthorn Woods (Lake)	1,658	4,423
Ingleside (Lake)	1,676	3,173
Island Lake (Lake)	2,293	4,449
Lake Barrington (Lake)	2,320	3,855
Lake of the Woods (Champaign)	2,443	2,748
Lena (Stephenson)	2,295	2,605
Long Grove (Lake)	2,013	4,740
Long Lake (Lake)	2,201	2,888
Mahomet (Champaign)	1,986	3,103
Maryville (Madison)	1,937	2,576
Metamora (Woodford)	2,482	2,520
Minooka (Grundy)	1,565	2,581
New Baden (Clinton)	2,476	2,602
Rochester (Sangamon)	2,488	2,676
Rockton (Winnebago)	2,313	2,928
Savoy (Champaign)	2,126	2,674
Shiloh (St. Clair)	1,045	2,655
Sleepy Hollow (Kane)	2,000	3,241
South Barrington (Cook)	1,168	2,937
Tilton (Vermillion)	2,405	2,729
Tolono (Champaign)	2,434	2,605

From Urban to Rural	1980	1990
El Paso (Woodford)	2,676	2,499
Kenilworth (Cook)	2,708	2,402
Marissa (St. Clair)	2,568	2,375
Mason City (Mason)	2,719	2,323
Pawnee (Sangamon)	2,577	2,384
Phoenix (Cook)	2,850	2,217
Rome (Peoria)	2,744	1,902
Trenton (Clinton)	2,504	2,481

Small-Town Romance

Surprisingly, at a time when small towns are losing people and declining in political importance, there is a renewed interest in understanding what made them desirable places in which to live. Contemporary interest in small towns arises from an unlikely source: architects and planners. Their interests lie not so much

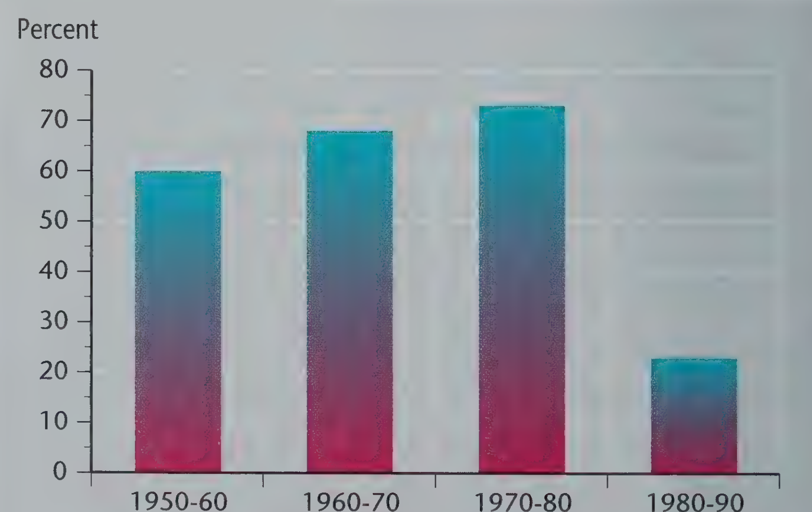


Figure 1. Percent of growth in rural communities: 1950–1990

Access to Health Care in Rural Illinois

Access to health care is a growing problem for citizens of the state's rural areas and for policy makers. Rural health-care providers and consumers are facing hospital closures; physician shortages — especially in prenatal and obstetric care — working people who are uninsured; large numbers of Medicaid and Medicare patients; a deteriorating emergency medical transportation system; rising health-care costs; government and private sector conflicts over who should bear the cost of treating the uninsured and the underinsured; and a growing reliance on advanced technology and specialty practices by physicians.

Twenty-five counties in Illinois, located mainly in the western, southern, and southeastern regions, have been designated health professional shortage areas by the federal government. Twelve other counties have service areas that are designated health professional shortage areas. Thirty-four counties — including the seven southernmost counties in the state and other western and southeastern counties — have no obstetric services. Infant mortality rates in these counties are equal to rates in underdeveloped nations.

Privately insured consumers with adequate economic resources travel to regional medical centers for care. The migration of these health-care dollars to metropolitan areas, coupled with underpayment by the government for services to Medicaid and Medicare patients, compounds the fiscal plight of rural hospitals and outpatient service providers. These factors affect the viability of local rural economies. A 1992 report of the American Hospital Association states: "The population of rural areas is increasingly the poor, the elderly, and the uninsured."

Three years ago, the Illinois Rural Health Association was formed to work for the preservation and enhancement of the health of rural citizens in Illinois. The association's diverse membership is composed of health-care providers, administrators, researchers, educators, state and local government leaders, agricultural representatives, and interested citizens. The Illinois Rural Health Association advocates solutions for rural health-care issues in the state capital.

Politically, Illinois is an urban state with approximately nine million people living in six northeastern counties and three million living in the remaining ninety-six. The health-care needs of rural citizens must be addressed by public policy. For more information about the Illinois Rural Health Association, call 1-800-526-9943 or 309-298-1413. — *Louis DiFonso, executive director, Governor's Rural Affairs Council*

in reviving small towns, but in understanding the structural features that contributed to a feeling of community and a sense of place. What qualities helped create a community with a stimulating social atmosphere and active social life? According to a recent article in *Small Town* magazine, the expectation is that, once understood, these attributes could serve as a "framework for understanding what gives each town its quality and also for diagnosing ways in which current design decisions support or erode that quality...." A dominant and recurring theme in these efforts is a dissatisfaction with suburban settlements that, architects believe, fail to function as communities. Thus the search for the sources of affection toward small towns in this "vernacular architecture" of the nineties is underpinned by a reaction against suburban growth and urban sprawl. The latter have contributed to creating a habitat where civic life is fragmented and economic classes are segregated, the antithesis of the American small town. What small towns enjoyed were:

- strong, defined boundaries and centers
- neighborhoods that could easily be walked
- residential areas that were not exclusively residential and were connected to the rest of the community
- buildings of varying size, value, architectural style, and disposition toward the street
- on-street parking
- trees
- sidewalks that encouraged pedestrian traffic
- narrow, lined-up streets

These attributes brought people out of their homes to stroll and loiter, to meet people unlike themselves, a phenomenon eloquently described by Andres Duany and Elizabeth Plater-Zyberk in their article, "The Second Coming of the American Small Town." All of this produced a sense of place and a feeling of community.

By studying old town plans and the layout of small towns, architects are incorporating some of their features into what Philip Langdon in a 1988 *Atlantic* magazine article referred to as "neotraditional towns." As part of the effort to recapture the aesthetic and social appeal of small towns, these new developments, according to Langdon, include:

- multi-story homes set back from the pavement
- front porches and fences
- narrow, straight streets that have a visual termination point or are tied to a downtown
- different styles of housing which accommodate a wide range of income groups
- landmarks that help people orient themselves within the community
- trees as boundaries providing spatial definition
- a mix of offices, shopping, and other services
- garages at the backs of lots

Small towns cast a unique shadow across the rural landscape. The ball field on a warm summer night brings a sense of community sharing to rural residents.

The distinguishing trait of these developments is "harmonious diversity." Whether these designs are sufficient to infuse new developments with a pride of place or sense of community remains to be seen.

So much has changed over the last century that it's appropriate to raise serious questions about whether these developments will become more than the suburbs they purport to replace. There are more dual-earner families who work away during the day, hardly a condition to promote psychological identification with the community, whatever its design. Family sizes are smaller, and there are fewer children to support the civic life that once flourished in small towns. Finally, people settling in suburbs are motivated perhaps as much by security and privacy concerns as they are for a feeling of community or an active public life.

Prospects for the Future

As we approach the next century, thoughts turn to the future of present-day rural communities. What might be done to ensure their survival, if not improve them? For many of those located along the thousands of miles of interstates, or near a fairly large urban area, the future doesn't look so bleak. Not only are they surviving, they are doing well. The problem for state and local government is deciding how to help the hundreds of small communities not favorably situated, those whose very existence was tied to agriculture and low-skilled manufacturing.

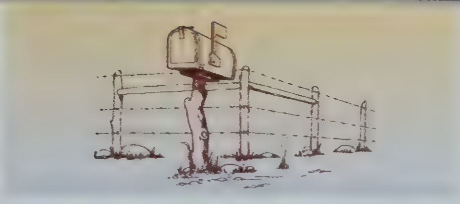
Society is ambivalent toward small towns. On the one hand, there is a prevalent feeling that they have cast a unique shadow across the rural landscape and have provided an alternative lifestyle to urbanism. On the other hand, some experts view them as being relatively insignificant to the economic welfare of the state and a diversion of resources away from greater needs. How much of the government's resources should be directed toward the rural communities that have literally been left behind and contain less than 10 percent of the state's population? More importantly, what can be done? These are the questions that puzzle both lawmakers and the small segment of the population still living in them.

Small towns, regardless of how current residents or even city people feel about them, face some major challenges. For some their very basis for existence has virtually disappeared. Many have few of the attributes necessary to diversify or grow. They're small, populated with older persons, located off the main interstates or not in particularly scenic areas, have poorer educational systems, and fewer of the types of amenities that would attract or retain residents. Many are governed by part-time public officials without the skills or resources to do more than maintain community populations. The dispersed pattern of settlement makes small communities difficult and expensive to service. To top it off, they have limited financial resources to promote development and they face a lot of competition for new firms, according to rural sociologists Thomas Daniels and Mark Lapping.

In government circles, there is talk about "rural revitalization," but that is merely a dream except for those small towns which are, by virtue of luck, in a good location or manage to develop through heroic local initiative. A new attitude is emerging toward rural communities, one which essentially recognizes that many rural communities cannot and will not develop. On the possibility of "success" in improving small towns, Coates, Jarratt, and Ragunas, in their recently published article, "Reviving Rural Life," argue for the more realistic position that any town can succeed, but not all will. Some have succeeded as retirement communities, government and area trade centers, recreation communities, exurbs, and academic communities.

Political attention has a way of shifting toward areas of growth and where the votes are. Rural areas aren't growing, contain relatively few people, and all their votes pale against those of the northern suburbs. Schneider describes the present as the "dawn of the suburban era in American politics." It is unlikely there will be major governmental initiatives to improve rural areas. Instead, the likely ingredient for rural development will be provided by the initiatives of local groups and individuals attempting to retain employment in rural areas, working to improve education and the local infrastructure necessary for attracting the knowledge-based jobs of the future.

Andrew J. Sofranko, professor of rural sociology, Department of Agricultural Economics ■



Taking Care of Business in Rural Illinois

Tina M. Prow

A quieter, slower pace; room for children to grow; friendly, dependable neighbors; family nearby; fields and flowers and trees outside the doorstep — these idyllic rural images make up a quality of life that anchors families to rural areas and draws back those who leave. For many, the commitment to a rural lifestyle in the face of tough economic times requires creative, and sometimes unconventional, career shifts.

Some become entrepreneurs, building businesses out of little more than a determination to live at the end of a gravel road. Some develop an interest or hobby into another career. In achieving their goals, they support their families and their communities as well, often making it possible for other families to live in rural areas. The following profiles introduce individuals whose initiatives, combined with grass-roots efforts, brought new jobs to rural Illinois.

Grain, Carts, and Computers

Three people are employed at the Layden farm now that the family also manufactures carts for welding tanks. Committed to farming for the past century, the Laydens produce grain on 2,700 acres east of Hoopeston. Although Ezee Roll Manufacturing Company, Inc. is unrelated to farming, it fits their farming goals.

The cart business developed five years ago out of a need for rainy-day and off-season work to keep experienced help on the farm. When the demands of farming slow down now, employees build carts in a shop on the farm. The carts, sold through specialty catalogs, are shipped all over the world.

"Strangely enough, we showed a profit from the beginning with this cart; that's not something we're used to in farming," Paul Layden said. Retired from the farming operation handled now by his son, Mark, the elder Layden spends much of his time making sales calls.

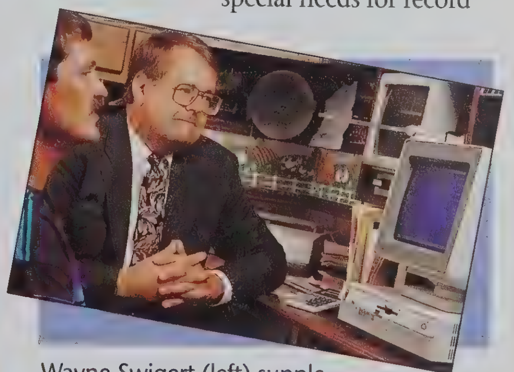
"In the past five years, we've watched many of our neighbors go broke. We're still solvent and would have been without the cart business, but it makes things a little easier. And it's nice to have something else to think about when farming gets really bad."

Paul Layden (left) started Ezee Roll Manufacturing Company five years ago to take up the slack during off-season time on the farm. Although retired from farming, he continues to make sales calls for the family cart business while his son, Mark, (right) handles the farming operation.

A similar need for something to supplement farming attracted Wayne Swigert to computer sales. Swigert and his wife, Judy, returned to a 1,000-acre corn-and-soybean farm north of Taylorville after graduating from the University of Illinois a decade ago.

"We found that farm life had changed," he said. "In the economic climate of the early '80s, off-farm income was very important." Tapping into a fascination he developed for computers while earning his degree, Swigert began working with a company that packaged software. His wife bought a store in Taylorville.

Today, Swigert works for a Springfield computer software store, primarily with their farm clientele. These clients have special needs for record



Wayne Swigert (left) supplements farming with his work in computer software, primarily with a farm clientele. Although his job is a sideline to farming, it is important for personal as well as financial reasons.

keeping that are not met by standard business software packages.

"I have a niche, and that's recognized in terms of what hours I work. When I'm in the field, so are my customers; those rainy spring days when farmers are catching up are when I get my calls," Swigert said.

Although still a sideline to farming, that "niche" job is increasingly important for personal, as well as financial, reasons, Swigert said.

"The more I farm, the less interesting it is, possibly because it's not profitable on a continual basis — there have been some very tough years in the past five years," he said. "But I still want to live in a rural area. I still want a large yard and a garden and room for the children to play. And that makes it all worthwhile."

True Grit and Determination

The garden and room for children to play motivated Ginger Prior to develop a business and career she never envisioned for herself. But like many families in southern Illinois, the Priors fell victim to coal company cutbacks in the late 1980s. Prior was determined to control some of the change that came to their lives.

"My husband had other job offers, but our family was here; we'd lived here for 23 years, and our son was 15. We didn't want to give up that feeling of support and friendliness we get from the neighbors," Prior said. "Staying meant a lot to all of us; we're fortunate that we got an idea for which way we were going to go the rest of our lives."

The direction she chose led to a $1 million business with a $500,000 payroll for 22 employees. Based outside of Benton and within steps of the Prior home, General Belt Service, Inc. offers repair of conveyer belts used in power plants and coal mines. Part of the service includes going underground to vulcanize belts, a process that fuses belt material. Plus, the company has a shop for sizing and reconditioning belts. The work keeps two shifts busy five days a week.

"We're local, so we can do much of the work cheaper than other companies. And we're the only minority business," Prior said. As owner of the business, Prior handles insurance and financial matters and represents the business to clients and unions. The family-based company also includes her husband, who brought supervisory skills from a 19-year career with the coal mines to the business; a brother with 13 years of vulcanizing experience; a sister-in-law; and a son.

That the business exists is testimony to Prior's determination to stay rural. Two banks turned down her application for $30,000 to buy vulcanizer equipment. She turned down a small business loan when the paperwork was made out in her husband's name. The turning point came when she remembered a presentation on rural development given years earlier by Norma Turok, an Extension small business management educator.

"Norma was there for me day and night with advice and help — I couldn't begin to hire someone to do what she did for me when I was just starting out," Prior said. "Basically, she helped me develop a business plan and a sales pitch that would convince a bank that this idea was going to work, that we had an edge, and that we'd create jobs.

"Then I bought the black business suit, did my nails, put the girdle on, and went to another bank."

Three meetings later, she had a loan.

Prior opened shop in January 1989, and repaid the loan within a year. The business since has expanded to seven vulcanizers.

"It's stressful. As owner, my main concern is to make sure the cash flow is coming through,

There's no place like home for Ginger Prior, whose desire to remain in a rural community led her to develop a $1-million business repairing conveyer belts.

Francis Land (standing, right) had a dream that brought her from a Chicago university to the Shawnee National Forest, where she developed Bay Creek Ranch Campground. She and Ray Morris (left), interim CES educator in tourism for Johnson County, talk with guests on a horse camping vacation.

so I'm financially worried to death constantly, and that's before I even begin to think about insurance. I bleach my hair every three months now."

"But I can bake cookies for my 8-year-old and run the business, and that means a lot to me. The men can have lunch at a picnic table under the trees and enjoy the flowers. I think that means something to them: they're all from rural areas," she added. "If we expand, we'll stay in a rural area."

From Campus to Campground

The picnic table under the trees is also a draw to those in urban areas, as Francis Land found over the years. Approaching retirement from teaching and research in marketing and advertising at Roosevelt University in Chicago, she looked for a business that would be fun and keep her active. She settled on running a camping area near Simpson, just outside the Shawnee National Forest.

"I was fascinated with the Shawnee area," said Land, an equestrian. "It reminded me of my home in rural North Carolina — church, neighbors, and real friendliness. The people I've met here are great to work with, a little southern in their speech and manner and attitude toward life. It's a very relaxed place."

Land said her Bay Creek Ranch Campground draws people from six states into Pope County to camp, ride horses, hunt, bird watch, and hike. Based on tourism data and her own experience, she estimated that each person on a horse camping vacation spends about $65 a day on food, fuel, camping fees, and other purchases.

"By having a business here and attracting people in, I'm bringing dollars into the community, and those dollars turn over an average of 3.2 times before they leave the community," she said.

Land offered the community something more when she chose to go into business: refurbishing and upgrading plans called for contractors, carpenters, machine operators, and people to staff a small restaurant. She hired two crews of teenagers to build fences. A full-time manager was brought in to oversee day-to-day operations. She had brochures and business cards printed and plans to advertise the campground.

"With double-digit unemployment, people are extremely happy to have an opportunity to earn money, and they welcome most new businesses with open arms," she said. "You pump money into the community — you're a mini-economic development opportunity."

Land's campground offered limited, primitive camping in 1991, while remodeling was under way, and officially opened the following spring. Business has been slow, she said, possibly because of the economy. Still, she is optimistic.

"This is the retirement business for me. I like horseback riding, and there are psychological and overall health benefits to being in a business that keeps you fit in your 50s. Plus, my back door is the Shawnee National Forest.

"I think this is a heck of a good way to meet congenial people, make a living, and have fun."

Tina M. Prow, science writer, Illinois Agricultural Experiment Station ■

Harmonious Diversity in the Landscape

Gary L. Rolfe

Each of us depends on the diversity of the surrounding landscape to provide many of our basic needs, such as food, protection for our soil and water, an aesthetically pleasing place to relax, a place to explore and pursue a variety of recreational opportunities, shelter, wildlife habitat for our enjoyment, and a myriad of other values. In many of Illinois' rural areas, however, the landscape has become too simplified to provide these multiple values in a sustainable manner. Our prairies, forests, and wetlands have given way to the plow and suburban sprawl. A once complex landscape is now a simple one, providing only a fraction of its previous values.

Consider a typical central Illinois landscape. The land stretches as far as the eye can see with few trees, fencerows, lakes, or ponds. Why is this? The answer is to maximize agricultural production. These large fields are more efficient for today's farm equipment, allowing lower production costs and maximum production. Farmers in all parts of rural Illinois have adopted this same farming system, resulting in a constant reduction in landscape diversity. Even today we still see forests, fencerows, and stream margins cleared to put more land into production. The societal costs of these land-use changes that decrease landscape diversity are staggering, but so poorly quantified they are easily ignored. It is difficult to put an accurate dollar value on downstream sedimentation, lowered water quality, loss of wildlife habitat, loss of aesthetics, and loss of other values that

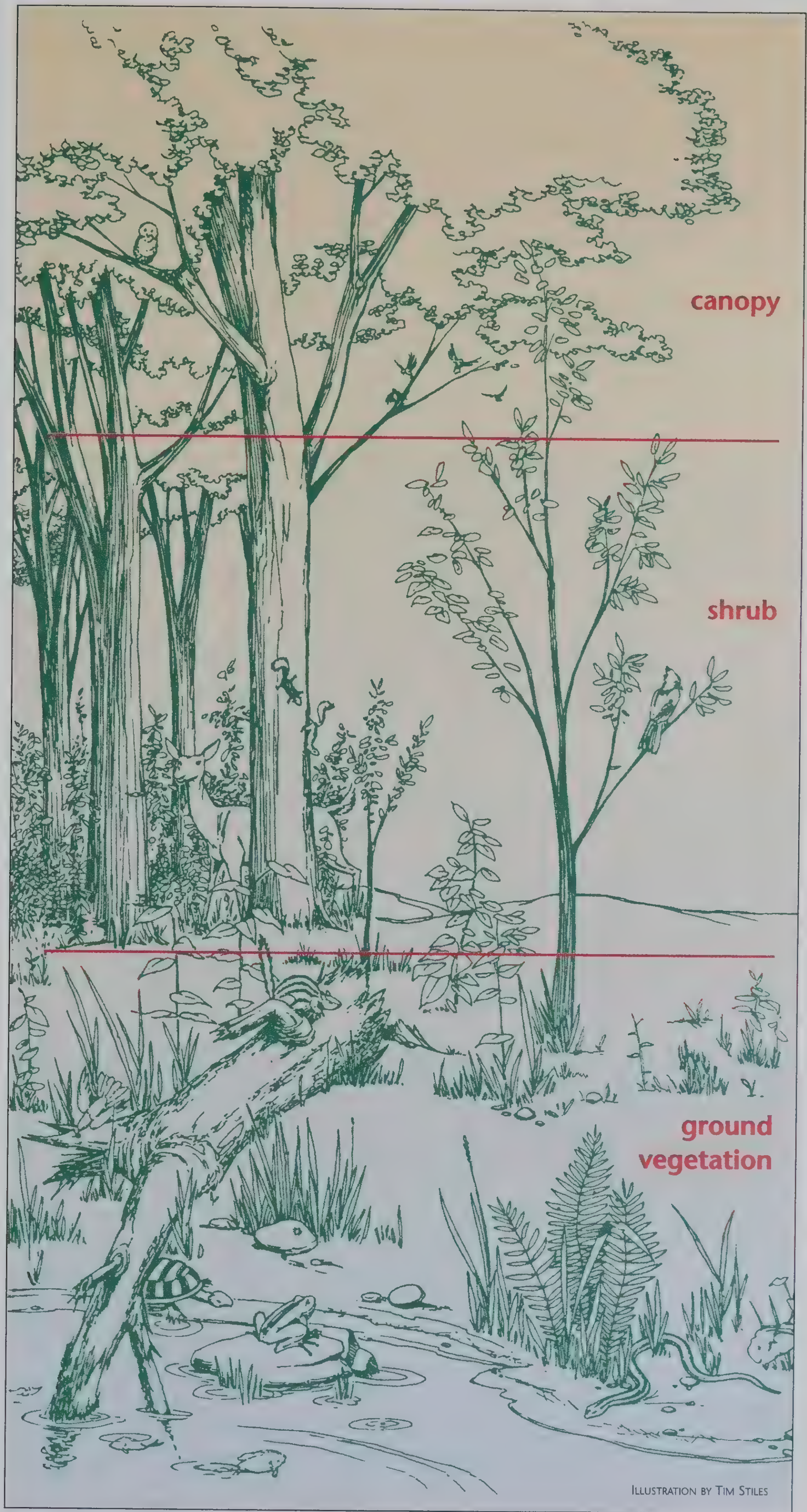
A stretch of typical central Illinois landscape is dramatically enhanced by the addition of windbreaks, fencerows, a few travel corridors, and even a small pond.

only a diverse and complex landscape can provide.

To illustrate the gains and losses through enhanced landscape diversity, consider the issue of fencerows or windbreaks. Introducing wooded margins to fields is clearly a way to enhance the diversity of our landscape, but seemingly has few followers in many parts of rural Illinois. Historically, windbreaks and wooded fencerows were once popular across the state. In the past 30 years, however, the tendency was to remove them. The great reduction in total forest acreage in Illinois over the past 100 years has left fewer natural forest-field interfaces. These edges between forest cover and fields are extremely important. In ecological terms, they are known as ecotones. Ecotones or transition zones between different types of plant cover are important because they provide homes for a greater diversity of plant and wildlife species. As two or more types of vegetation come together, an environment is established that includes elements of each, creating more places for plants and animals to live and a resultant increase in the variety of life forms. This complexity makes for a more stable ecosystem, one that we generally consider aesthetically pleasing.

Layering Provides Homes

Stratification or layering is another ecological relationship important in fencerows and natural woodlands that are interspersed across the landscape. Forests, in contrast to agricultural fields, offer several layers of vegetation — a layer of low plants along the ground; a layer of shrubs and two or three layers of trees; and saplings, intermediate-sized trees, and full-sized trees. This is important because each layer provides a different type of home for insects, birds, and animals. For example, some birds feed and live on the ground, while others inhabit the tree canopy. This diversity in living places for organisms is significant because it allows nature to sustain a greater variety of living forms. This, in turn, is vital to us because the complexity of organisms results in greater stability to the world and allows nature to maintain itself. In agri-



A variety of living forms occupy the natural woodlands interspersed across the landscape, from aquatic life, to ground dwellers, to birds in the tree canopy.

culture, humans assume responsibility for maintaining the production system. We reduce competition from other organisms and provide nutrients, in some cases even water, to channel production on to the crop species of our choice. This provides a good food supply, but leaves the ecosystem unstable and subject to disruptions such as erosion and nutrient loss. Consequently, we must put increasingly greater energy inputs into the system in order to maintain it in a productive state and minimize these disruptions to adjacent ecosystems.

Fencerows, windbreaks, and forests provide these needed ecotones and layers of vegetation. They also reduce windspeed and modify the microclimates of the nearby fields. Windspeed reduction varies with the characteristics of the windbreak, including density, species, and height. Generally, windbreaks reduce windspeed for a distance of 10–15 times the height of the trees on the downwind side and 3–5 times the height on the windward side. In other words, a windbreak of 60–foot trees would reduce windspeed downwind by 600–900 feet. This is important because the ability of the wind to carry soil particles varies directly with the cube of the wind velocity. For example, if the windbreak reduces the velocity to half of its initial value, the carrying power to move soil particles is reduced to one-eighth of its initial value. Soil protection is greatly enhanced by the use of windbreaks, especially when combined with good cropping practices. The reduced windspeed over the adjacent field also decreases water losses by evaporation and transpiration from the crop area, thereby protecting crop moisture supply longer into the growing season. A windbreak does remove a certain amount of land from production, but most research shows no loss in total crop production and even gains in areas with great exposure to wind.

Rows of trees or forest vegetation also reduce the surface and subsurface flow of water and nutrients. Forested stream margins also provide excellent protection by reducing soil loss and stream sedimentation and improving water quality, all direct benefits to society and the farmer.

Our simplification of the landscape may indicate that we simply do not understand the important relationship between a more diverse landscape and our lives.

Recent research has demonstrated that rows of trees and forested stream margins serve as effective filters capable of removing significant quantities of plant nutrients. A significant factor in effectiveness of these forested areas is the size of the buffer zone. Larger areas of trees are more effective, but even narrow margins are important and offer soil and nutrient conservation.

Safe Travel Pathways

Fencerows provide wildlife homes and cover and travel corridors for a variety of species. It is commonly argued by the agricultural community that fencerows harbor animal and insect pests that cause considerable crop damage. However, increasing evidence shows that fencerows also maintain predators that feed in fields and reduce agricultural crop loss by reducing pest populations. The role of birds as pest predators is also quite important in reducing insect pest populations adjacent to fencerows. Fencerows and windbreaks are also travel pathways that allow animal movement. During most of the year when crop fields are bare, many species of wildlife have difficulty moving without being exposed to potential predators. Fencerows and natural woodlands interspersed throughout the Illinois landscape can provide safe travel pathways.

Fencerows attached to a natural woodland patch are of even greater importance. Plant, insect, bird, and animal colonization of fencerows and movement are greatly enhanced when adjacent to natural woodlands. Populations are increased in both the woodland and the fencerow. Seed dispersal of many plant species occurs as birds and animals travel along and within fencerows. Large patches of woodland of 200 or more acres also provide an opportunity for survival of species that rely on the forest interior for breeding. These woodland patches offer an ideal landscape when connected to other patches by fencerows or stream margins.

Fencerows are important to the farmer and society in many ways, including reducing wind and water erosion and nutrient loss, providing wildlife habitat and a more aesthetically pleasing environment, providing shade, marking property boundaries, providing firewood and landscape diversity, and harboring potential predators of crop pests. On the downside, fencerows may harbor crop pests, block or impede farm machinery, and take land out of crop production. Forested stream margins, windbreaks, and natural woodlands offer the same advantages and disadvantages.

Each of us sees our surrounding landscape in different ways. We may view it as habitat for wildlife, for its production possibilities and potential wealth, for its aesthetics, for its history, or simply for the way viewing the landscape makes us feel. These feelings may include beauty, pride of ownership, belonging, danger, a place to work, and countless others. The combination of how we view the landscape and our resultant feelings governs how we treat the landscape. This in turn tells us much about our personal values and what we consider important. Our simplification of the landscape may indicate that we simply do not understand the important relationship between a more diverse landscape and our lives.

In viewing the Illinois landscape, we should ask if what we see reflects our values and, if not, make a commitment for change. By restoring some of the diversity back to Illinois' landscape (through increased tree planting, for example), we can examine the values a diverse landscape provides and renew our commitment to making rural Illinois a more pleasing and better place to live and work.

Gary L. Rolfe, acting associate director, AES; professor, forest ecology and environmental studies; and head, Department of Forestry

Tourism and Recreation in Illinois

A diverse landscape is a crucial element for a successful tourism and recreation industry in Illinois. If tourism is to grow, we need to alter the image that both visitors and residents have of Illinois, one that calls to mind Chicago, Abraham Lincoln, corn, and soybeans. Although these are important elements in the state's culture and economy, Illinois has far more to pique the traveler's interest.

Many of the state's natural features have landscape and cultural characteristics that are outstanding in their own right. For example, the river valleys of the Mississippi, Rock, Illinois, Kaskaskia, Wabash, and Ohio rivers; the Shawnee Hills of southern Illinois stretching from river to river; the shoreline of Lake Michigan, "Our Greatest Lake"; and the unglaciated features of northwestern Illinois. Although the central Illinois farm fields lack landscape diversity, they definitely have a character unique to this area of the Midwest. Local photographers and artists, such as Larry Kanfer and Billy Morrow Jackson, have captured this uniqueness in a way that enables people to understand and appreciate the latent beauty of this large, flat, open land form. "Beauty is in the eye of the beholder," and different people have different perceptions of beauty in the varied landscapes of Illinois.

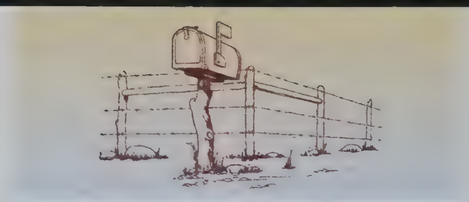
In addition to outstanding landscape features and regions, both in urban as well as rural areas, Illinois contains many subregions that are basically rural in character. A question often raised is, "Can we really interest people in this area and market our assets successfully?" Out-of-state and foreign visitors, as well as urbanites, are attracted to Illinois' small towns and rural, agricultural areas because of our tremendous agricultural production and related agribusiness. For nostalgic reasons, many visitors want to relive life in a small town or relive the farm life of their childhood when visiting rural relatives. They're often interested in touring an operating farm, a grain elevator, a processing plant, and even staying on a farm for a few days to a week. Are there similar places for people to visit or tour in your area?

Providing bed and breakfast to travelers is an activity on the rise in Illinois, both in country and urban areas. A significant number of the newer places are located in small towns or on farms, meeting a critical need by providing housing for tourists where none exists or where there is little likelihood of building a motel or lodge. Encouraging and helping local people develop a successful bed and breakfast keeps revenue in the community and allows them to live in a small town while making a larger contribution to the economy. (Further information can be found in *Developing a Bed and Breakfast Business Plan,* NCR273, available through the University of Illinois Cooperative Extension Service.)

There is no question that tourism can and should play a key role in the rural revitalization efforts in Illinois and throughout the nation. Although tourism is not the only answer to an area's economic woes, it is an important element in the long-range strategy for economic revitalization. A thorough analysis of the tourism assets found within an area or region is a necessary step in developing a marketing plan and creating a good program. Not every area has the scenic, historic, or cultural resources that another will, but each has some unique resource that can be appropriately marketed. The community, county, or region cannot afford to take a parochial outlook on tourism; maximum cooperation is essential for a successful tourist industry.

Illinois, with its outstanding resources and opportunities, has a great deal more to offer in the tourism picture than most people realize. But we must work together to enhance tourism by wisely developing these assets and presenting a positive image to citizens and visitors. — *Robert D. Espeseth, recreation resource specialist, Office of Recreation and Tourism Development, Department of Leisure Studies, Cooperative Extension Service*

By providing bed and breakfast to travelers, rural residents are able to remain in the community while contributing to its economic growth. The River Rose Inn is found in Elizabethtown on the banks of the Ohio River.



The Rise and Fall of the Illinois Economy

John B. Crihfield

In his 1992 C. Woody Thompson Memorial Lecture to the Midwest Economics Association, Professor Sherwin Rosen of the University of Chicago spoke on the decline of the Midwest. However one defines this Midwest, Illinois is a big part of it, accounting for almost 20 percent of the population of the Census Bureau's 12-state Midwest division. It should come as no surprise, then, that the same long-run economic forces that shape the Midwest are also shaping rural and urban Illinois. Illinois' share of U.S. population peaked at about 6.3 percent between 1900 and 1930 and has fallen steadily ever since. There is considerable evidence for the state's relative decline and reason to believe that these trends will continue. What is more, there is little the state can or should do to counter the trends.

Government agencies have accumulated economic data about Illinois and the Midwest for over a century. Some of these data are crude, especially for earlier years, and some data series go back farther than others. However, major trends are unmistakably clear in these data. Except for total population, which has been tabulated since colonial times, the accompanying tables report state and regional data from the earliest recordings. In some cases, data for Illinois are unavailable in published documents. However, data are usually available for the Midwest, defined in the tables as the East North Central states (Illinois, Indiana, Michigan, Ohio, and Wisconsin). Also shown for comparison are data for the South Atlantic states (Delaware, Florida, Georgia, North Carolina, South Carolina, Virginia, and West Virginia) and the Pacific states (California, Oregon, and Washington). These two regions are part of the Sunbelt that has grown so rapidly in recent decades.

Table 1.
Population of Illinois, the Midwest, and other regions

Year	U.S.	ENC		SA		P		Illinois		Illinois Urban		Illinois Rural	
	Level[a]	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[c]	Level[a]	%[c]
1860	31,443	6,927	22.0	5,365	17.1	444	1.4	1,712	5.4	246	14	1,466	86
1900	76,094	16,002	21.0	10,458	13.7	2,428	3.2	4,822	6.3	2,616	54	2,205	46
1940	131,954	26,725	20.3	17,935	13.6	9,776	7.4	7,897	6.0	5,810	74	2,088	26
1980	226,546	41,682	18.4	36,959	16.3	31,800	14.0	11,427	5.0	9,518	83	1,909	17
1988	245,807	42,119	17.1	42,426	17.3	37,351	15.2	11,614	4.7	NA	NA	NA	NA

[a] In thousands.
[b] As a percent of U.S. population.
[c] As a percent of Illinois population.

NA: Not Available; ENC: East North Central; SA: South Atlantic; P: Pacific.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis, *Long Term Economic Growth: 1860-1970,* Washington, D.C., 1973.
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Bureau of Economic and Business Research, University of Illinois at Urbana-Champaign, 1991 *Illinois Statistical Abstract.*
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U.S. Department of Commerce, Bureau of the Census, *County and City Data Book: 1983.*

The Shrinking Farm Population

Since Abraham Lincoln's presidency, population in the United States has grown sevenfold (Table 1), and populations in all regions increased enormously. Since the turn of the century, population growth has been faster outside Illinois and the Midwest. Within Illinois, the percentage of persons living in rural areas (roughly, places of less than 2,500 persons) has dramatically declined. At Lincoln's inauguration, 86 percent of Illinois' population lived in rural areas; by 1980 only 17 percent did.

One reason for the declining rural population is the shrinking farm population. In 1900, 28 percent of Illinois' population lived on farms; by 1980 less then 3 percent did (Table 2). This was not just relative decline: the number of persons living on Illinois farms fell 76 percent during this period. Powerful economic forces were behind this change. Farm productivity increased dramatically with technological innovations and increased mechanization on farms. However, even with expanding export markets, demand for farm products did not grow nearly so rapidly. At the same time, demand for processed goods rose steadily, and much of the surplus labor from farms in this country and from foreign immigrants became absorbed in the growing urban manufacturing industries.

Tables 3–5 illustrate these developments. Although the value of farm products has increased over time, the relative importance of farm output has declined steadily (Table 3). Farm products now represent about 3 percent of Illinois output; in the last sixty years they never accounted for more than 9 percent. Trends are similar in all other regions of the country.

Competition from the Sunbelt

Table 4 illustrates the rise in manufacturing during the first half of the century. Much of this activity was located initially in Illinois and elsewhere in the Midwest. But like farming before it, fortunes turned against manufacturing soon after World War II, especially in the Midwest, with a slight decline in midwestern manufacturing employment since 1950. Although U.S. manufacturing employment has been relatively stable during this period, there were important manufacturing employment gains in the Sunbelt. As in farming, important productivity gains exist in manufacturing because of innovations. Investment has also been attracted to low-wage Sunbelt states and even overseas. At the turn of the century, large midwestern cities offered comparative advantages in terms of access to a plentiful supply of farm and immigrant labor, raw materials, and final markets. Today, labor is no longer so plentiful and cheap in the Midwest, the raw materials of coal and iron ore are less important, and final markets are more dispersed.

The net effect of these forces is reflected in Table 5. In 1880, output in the Midwest was almost three times greater than in the South Atlantic and almost fives times as large as in the Pacific. A century later these regions have roughly equal shares of output and income.

The recent record is reported in Table 6. Even for this relatively short period (1978–1989), the long-run trends are apparent. Total employment in Illinois grew by 11 percent, but it grew twice as fast in the rest of the country. Within Illinois, almost all of the growth occurred in metropolitan counties (i.e., counties that are part of government-defined metropolitan areas). Farm employment continued its decades-long decline, but at a much faster rate in Illinois than

Table 2.
Farm population in Illinois, the Midwest, and other regions[c]

Year	U.S.		ENC		SA		P		Illinois	
	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[b]
1900	29,875	39.3	5,653	35.3	5,271	50.4	690	28.4	1,341	27.8
1940	30,547	23.2	4,638	17.4	6,060	33.8	1,270	13.0	979	12.4
1980	5,618	2.5	1,322	3.2	619	1.7	342	1.1	314	2.8

[a] In thousands.
[b] As a percent of total population (see Table 1).
[c] "Farm population" is rural civilian population living on farms, regardless of occupation.
ENC: East North Central; SA: South Atlantic; P: Pacific.
Sources: See Table 1.

Table 3.
Value of farm products as a percentage of total personal income[a]

Year	U.S.	ENC	SA	P	Illinois
1930	11.2	7.9	12.7	12.5	6.2
1950	9.8	8.0	8.3	9.8	8.5
1969	5.8	4.6	4.5	4.8	5.2
1987	3.4	3.1	2.5	3.1	3.0

[a] Value of farm products sold does not include government payments received by farm operators. Personal income data are for the years 1929, 1950, 1970, and 1988.
ENC: East North Central; SA: South Atlantic; P: Pacific.
Sources: See Table 1.

Table 4.
Manufacturing employment in Illinois and selected U.S. regions

Year	U.S.		ENC		SA		P		Illinois	
	Level[a]	%[b]	Level[a]	%[c]	Level[a]	%[c]	Level[a]	%[c]	Level[a]	%[c]
1899	4,850	16.7	1,177	24.3	483	10.0	133	2.7	NA	
1919	9,837	23.6	2,835	28.8	897	9.1	485	4.9	NA	
1939	9,527	19.2	2,693	28.3	1,111	11.7	523	5.5	NA	
1950	14,770	24.5	4,427	30.0	1,627	11.0	1,037	7.0	1,190[d]	7.1[d]
1982	19,094	17.1	4,152	21.7	2,930	15.4	2,518	13.2	1,077	5.6
1989	19,943	14.7	NA		NA				1,000	5.0

[a] In thousands.
[b] As a percentage of "gainful U.S. workers" for 1900, 1920, 1940, and 1950, and "total U.S. employment" for 1979 and 1989.
[c] As a percentage of U.S. manufacturing employment.
[d] 1958 data.

NA: Not Available; ENC: East North Central; SA: South Atlantic; P: Pacific.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis, *Long Term Economic Growth: 1860-1970,* Washington, D.C., 1973.
U.S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States: Colonial Times to 1970,* Washington, D.C., 1975.
Bureau of Economic and Business Research, University of Illinois at Urbana-Champaign, 1991 *Illinois Statistical Abstract.*
U.S. Department of Commerce, Bureau of the Census, *1990 Statistical Abstract of the United States,* Washington, D.C., 1991.
U.S. Department of Commerce, Bureau of the Census, *County and City Data Book: 1983.* 1967 and 1988 *County and City Data Books.*

Table 5.
Total personal income in Illinois and selected U.S. regions

Year	U.S.	ENC		SA		P		Illinois	
	Level[a]	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[b]	Level[a]	%[b]
1880	8,740	1,997	22.9	689	7.9	398	4.6	NA	NA
1900	15,390	3,455	22.5	1,086	7.1	800	5.2	NA	NA
1940	78,122	17,751	22.7	8,163	10.5	7,613	9.8	5,958	7.6
1981	2,406,545	443,643	18.4	366,887	15.3	380,138	15.8	132,638	5.5
1988	4,053,000	684,000	16.9	682,500	16.8	677,100	16.7	204,100	5.0

[a] In millions of dollars.
[b] As a percentage of U.S. personal income.

NA: Not Available; ENC: East North Central; SA: South Atlantic; P: Pacific.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis, *Long Term Economic Growth: 1860-1970,* Washington, D.C., 1973.
U.S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States: Colonial Times to 1970,* Washington, D.C., 1975.
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U.S. Department of Commerce, Bureau of the Census, *1990 Statistical Abstract of the United States,* Washington, D.C., 1991.
U.S. Department of Commerce, Bureau of the Census, *County and City Data Book: 1983.*

elsewhere. Manufacturing employment plunged 24 percent in the state, but fell only 5 percent in the rest of the nation. The major growth industries — wholesale and retail trade, financial services, and services in general — increased more rapidly outside of Illinois. Today the major employment sectors in Illinois, both in metropolitan and nonmetropolitan areas alike, are services, retail trade, manufacturing, and government. Even in nonmetropolitan areas, farm employment represents only 8 percent of total employment, and many of these farm employees work part-time in nonfarming jobs.

Given this long record, it seems likely that Illinois and the Midwest will continue to experience relative decline during the 1990s. Fertile soil and central location are less important now than in eras past. Southern and western states will continue to attract people and investment for many reasons: lower wages and land prices, weaker unions, and warmer climates. At some point, increased congestion and pollution along with higher labor and land costs will slow these developments, but it could be a decade or longer before the relative decline runs its course.

Tools or Gimmicks?

What options do state policy makers have for promoting economic development in Illinois in general, and in rural areas in particular? At the state or local level there is little governments can do to change long-run economic conditions. From the standpoint of long-run comparative advantage and resource productivity, often the best economic policy for the state government is not to counter underlying economic forces. Sound state and local economic policies include stable and predictable taxes and public expenditures. Unobtrusive taxes are proportionate to the benefits received from public activities, and the most productive expenditures are for services that are incompletely supplied in the private sector. However, many actions by the state in the name of economic development, rural or otherwise, are often taken

Population continues to decline in rural Illinois as in the rural Midwest. Can — or should — this trend be changed?

to satisfy influential political constituencies. As "economic development strategies," many do little or nothing to strengthen the state's underlying economy. Recent programs promoted as rural economic development tools, include, but are not limited to, the following:

- $35 million in state grants to help purchase scrubbers for Illinois Power's Baldwin plant. Touted as a way to save coal mining jobs in southern Illinois, this will raise costs for Illinois taxpayers, businesses, and consumers.
- Continuation of Illinois' sales tax abatement for corn-based gasohol. The vociferous claims of lobby groups notwithstanding, the net effect will cost Illinois workers and businesses over $50 million per year by the year 2000.
- Creation of the Illinois Rural Bond Bank in 1989. Through this bank, which now has issued over $11 million in bonds, Illinois taxpayers will subsidize rural public infrastructure using the "moral obligation" of the state to back relatively risky small rural loans.
- Community Development Assistance Program grants. In 1991 over $26 million

Table 6.
The Illinois economy today

	Percent Change in Employment, 1978-1989				Percent of Total Employment, 1989	
	U.S.	Illinois Metro	Illinois Nonmetro	Illinois	Illinois Nonmetro	Illinois
Total	26%	13%	3%	11%	100	100
Farming	–16	–27	–25	–26	8	2
Ag. Services	70	121	60	105	1	1
Mining	–8	–10	0	–6	2	0.5
Construction	29	21	–9	16	4	5
Manufacturing	–5	–25	–17	–24	16	16
TPU	18	10	10	10	5	5
Wholesale	23	16	5	15	4	6
Retail	31	15	11	15	16	16
FIRE	51	28	27	28	6	8
Services	62	55	41	53	22	28
Fed. Civilian	9	4	10	5	1	2
Military	13	5	20	6	1	1
State and Local Gov't.	14	0	–2	0	14	10

TPU is Transportation and Public Utilities; FIRE is Finance, Insurance, and Real Estate.
Source: *1991 Illinois Statistical Abstract.*

in federal block grants, administered through the Illinois Department of Commerce and Community Affairs, was awarded to subsidize public infrastructure in small Illinois towns and cities. Federally guaranteed loans through the Farmers Home Administration also subsidize rural housing and infrastructure.

- Loan subsidy programs offered by the Treasurer of the State of Illinois. Two of these programs are concentrated in rural areas: the Agriculture Loan Program and Community Health Partnerships. The first offers below-market rate loans to farmers and currently has nearly $200 million in deposits in 205 Illinois banks and credit associations. The second is an arrangement between the Treasurer's office and the Southern Illinois University School of Medicine to subsidize new physicians in rural Illinois. Taxpayers, and the Illinois economy in general, lose out because the Treasurer forgoes higher rates to support these rural activities.

None of these programs is justified on strictly economic grounds, in the sense of an efficient allocation of the state's resources and in promoting the state's comparative advantages. However, each program is small, relative to the state's economy, and none by itself attracts much attention. By far the most significant rural economic policy is federal. According to U.S. Department of Agriculture estimates, about 30 percent of farm producer income is created by agricultural trade barriers and domestic farm programs. These policies lead to higher domestic food prices, overproduction in farming, artificially higher farm land prices, and farm populations that, despite decades of outmigration, are still too high.

A sound rural economic development policy would shun the gimmicks. It is healthy that the fifty states compete vigorously for jobs and growth. Over time, those states using too much artifice in their economic affairs will be the long-run losers in their rural and urban areas.

John B. Crihfield, assistant professor, Department of Agricultural Economics and Institute of Government and Public Affairs

Public Intervention for Economic Development

Economic development is a prime concern in virtually every state, but it is especially important in Illinois. Although Illinois is still a prosperous state when compared with most other parts of the nation, our economy's rate of growth has slowed down in recent years. Illinois' share of the nation's population, employment, and income has declined significantly in the last two decades. Rural areas are more severely impacted by these changes than other parts of the state.

Increasing attention has been focused on the government's (especially the state's) role in promoting economic development. For example, a number of state programs have emerged in an attempt to stimulate development. It is important, however, to assess the strengths as well as the limits of government intervention.

The key point to remember is that a state's success or failure in the economic arena ultimately depends on the ability of its citizens and businesses to compete in the national and world economy. Success is achieved by individuals and organizations in the economy pursuing activities in which they have a comparative advantage.

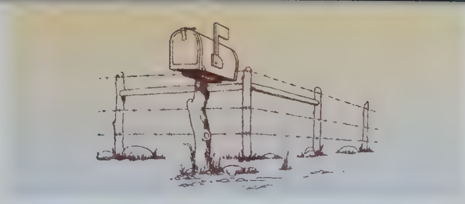
For the most part, governments (at least in the short run) have little ability to change the underlying forces that shape a state's comparative advantage. Attempts to hold back the tides of a changing world economy (such as the state promoting steel production in Chicago or coal production downstate in Illinois), often make the situation worse rather than better in the long run. Success depends on the ability of economic agents to adjust to new opportunities, but government policies in the past usually focused on helping people in their current situations. Change is often painful, but delaying this needed change only compounds the ultimate suffering. This suggests that direct aid to revitalize decaying cities or to regenerate stagnant rural areas is often well intentioned, but counterproductive.

There are, however, a number of things that state governments should do to promote development. For the most part, these involve general measures that apply widely in a state rather than targeted programs to help specific firms and industries. Areas that promote development include:

- The maintenance and enhancement of physical infrastructure, especially in the area of transportation.
- The enhancement of human capital through education at all levels.
- A tax climate that is stable and productive in financing basic services without being burdensome.
- A regulatory environment at the state and local level that achieves basic public goals without unnecessarily constraining economic activity.

These are policies that give the citizens of a state the ability to adjust and adapt to unexpected changes. They do not attempt to determine, however, the direction of the state's economy in the future.

Unfortunately, these general policies are difficult to implement politically. Very little political credit is given to a governor or representative who invests in education or physical infrastructure or who maintains a stable tax system. Politicians receive greater rewards for cutting ribbons at new factories, which they claim they have lured with some type of incentive, or for providing direct aid to urban and rural areas that are suffering economic distress. These short-run political gains are often not matched by long-run economic progress. — *J. Fred Giertz, professor of economics and member of the Institute of Government and Public Affairs, University of Illinois at Urbana-Champaign*



Rural Revitalization Strategies

John van Es

The recent history of rural areas of the United States, and for that matter all industrial countries, shows a continual inability to maintain their competitive positions in comparison with urban areas. In terms of investments, ability to provide services, and ultimately, ability to retain population, rural areas have long experienced decline. The particular combination of historical, technological, economic, and policy-driven forces has led to different responses in different countries. For example, many of the West European countries have pursued an active national policy of enhancing the viability of the countryside. They do this by supporting high levels of services and maximizing the economic opportunities and amenities available to people in rural areas.

Rural Decline

In general, federal and state policy in the United States can be characterized as allowing the major economic and historic forces to operate virtually unimpeded in rural areas. This is not to say that there are no capital transfers into the rural economy; agricultural support payments and individual transfer payments are just two examples of capital inflows into rural areas. However, these payments are not part of a broad-based rural-development policy aimed at modifying the impact of long-term economic forces. The result of existing policy, by most measures, can only be described as a drastic demographic, economic, and social decline of most of our rural areas.

It is argued that this decline will continue, and that we should develop a long-term policy to essentially guide this decline in ways in keeping with some broader societal objectives. For example, the concept of "triage," borrowed from medical emergency procedures, suggests an approach for deciding the most efficient allocation of the existing resources. Under a triage system, decisions would be made on where to allocate resources in rural areas in order to obtain maximum benefit. Understandably, local people who find that their community is one no longer chosen for continued investment reject this approach. Yet investments are being withdrawn from their communities on an ongoing basis. Note, for example, the decline in retail services, the closing of hospitals, and the consolidation and reorganization of many state and federal agency offices, primarily in rural areas. At present, decisions not to invest are made almost entirely by the individuals and agencies involved, according to criteria that protect the interests of their individual firm or organization. The long-term interests of rural residents or communities is rarely given full weight, and even when local interests are taken into account, decisions are typically made on an ad hoc basis without coordination among decision makers. As a result, the ability of these individual decisions to yield the optimal outcome for rural areas is left to chance.

The problem in the triage system is that those who make the decisions negatively affect the well-being of many rural residents and communities. Yet, if the medical profession can manage to develop an acceptable set of rules in matters affecting life and death, perhaps the political system should at least attempt to give serious thought to this approach. One of the challenging issues in a triage

Construction of an enterprise zone in Gibson City brings a smile to Mayor Karen Rhodes, who actively supports local leaders in revitalization efforts.

Illinois Institute for Rural Affairs

The Illinois Institute for Rural Affairs was created in 1986 by Governor James R. Thompson when the Task Force on the Future of Rural Illinois convinced him that a university agency should be established to research rural issues, recommend policies to state officials, and serve as a clearinghouse on rural projects. The Institute has statewide responsibilities and works with universities, foundations, and private agencies concerned with rural issues. It is located at Western Illinois University, but many of the projects funded by the Institute are conducted by faculty at other Illinois universities.

The Institute works in five main program areas: education, economic development, transportation, health, and public finance. These topics were selected because of their importance to rural areas, but also to minimize duplication of programs at other universities. For instance, the Institute defers work in production agriculture to the Cooperative Extension Service at the University of Illinois.

The Institute is conducting several projects to promote local economic development in rural areas. One program, "Mapping the Future of Your Community," is offered to small rural communities upon request. This program works with a committee of local economic development officials in three evening sessions. The first meeting identifies trends and examines recent community economic development. The city is compared with others of similar size, and city trends are compared with rural trends in Illinois. Participants view a videotape on visioning so that they realize the importance of local control in charting the future of their town. The meeting closes with community leaders creating a profile of what they want their community to be at the end of five years.

The second session assists local officials in setting short- and long-term goals. Community leaders prioritize goals and select specific community projects that will lead to the stated objectives. Participants then prioritize projects and begin creating an action plan.

During the third meeting, participants assign work projects and develop a timetable for completing them. Personnel from utility companies, the Cooperative Extension Service, and other state agencies attend the meeting to work with community leaders on specific projects. By the end of the third meeting, an action plan with assignments, a timetable, and an evaluation process has been drafted. Institute staff prepare a written record of the program for community leaders. A six-month review of progress is planned for the community, and Institute staff provide assistance as needed.

The Institute also conducts several research programs relating to economic development. During the past year, it examined the effects of new discount centers on surrounding towns and recommended ways that Main Street stores in these communities can compete successfully with large discount centers. The Institute, in cooperation with the Illinois State Chamber of Commerce, hosted a statewide satellite training program about the effects of Wal-Mart stores on small town Main Streets in Iowa.

With help from the Office of the Lieutenant Governor and Rural Partners, the Institute also hosts an annual statewide Rural Community Economic Development Conference. This conference features successful economic development programs in small Illinois communities and workshops in which participants learn to use economic development tools and techniques.

If rural communities are to manage the inevitable economic changes that will continue well into the 1990s, they must take charge of their futures. The Institute provides the materials and training opportunities to assist community leaders in adapting to changing economic times. — *Norman Walzer, director, Illinois Institute for Rural Affairs, Western Illinois University*

decision-making environment, in which investment in rural areas might be concentrated in certain communities, is which interests, in addition to local ones, will play a role. For example, the protection or creation of rural areas that might contribute positively to solving general societal problems could be a significant objective of such a policy. An extreme example has already been proposed by those who suggest that part of the plains states be abandoned by human habitation altogether and restored to its original state as the "buffalo commons." In Illinois, triage policy might lead to a decision to take some rural Illinois areas and "steer" their development toward meeting the environmental and recreational needs of urban residents, or towards the use of storage for nuclear and other wastes. Questions such as who would make the decisions, how to achieve fairness, and ultimately, who would control the destiny of local communities, are exceptionally challenging political, if not moral, issues. These issues are already being debated and resolved in rural areas under the relatively uninhibited operation of economic forces. How to obtain the desired outcome of rural development policies is a proper subject for political debate.

Education as a Response

In the absence of a significant interventionist federal or state policy to address the issues of rural areas, the strategies developed in response to economic and historical forces are largely based on the use of local resources. The most common local response to the decline of rural areas is to equip the residents of rural areas, especially the young people, with the best opportunities to compete in the more urban and industrial parts of our society. Many rural communities have invested heavily in education, enabling their young people to make the transi-

tion from rural areas into the urban labor force as successfully as possible. Especially in the Midwest, the heavy local investment in education has resulted in a highly mobile, adaptable, and successful labor force that has moved from rural to urban areas.

From the point of view of rural areas, the investment in education was generally not a deliberate rural outmigration policy; the high investment in human resources was justified on a variety of grounds, including a high value placed on educational achievement for its own sake.

Individual rural residents and society at large believe that the strategy of human resource development proved quite satisfactory. Their children were overwhelmingly successful in their transition to the urban labor force, many of them acquiring leadership positions in society. However, for migrants from Appalachia and much of the South, where rural areas have not invested heavily in education, the migration into the urban labor force has generally been difficult and painful.

However, not only did rural communities frequently spend a large proportion of their resources on education, they also saw the "value added" from this investment depart to other areas that ultimately benefited from the initial investment. Thus, the brain drain from rural areas has been and continues to be a significant transfer of rural resources to other areas. Even those rural communities that have historically invested in education now find it difficult to gather the resources to adequately prepare their young people for the transition to an ever-demanding labor market.

The education experience provides an opportunity to illustrate to some extent the potential outcome that could be obtained from an alternative rural development policy. A general policy to protect the resources of rural areas could have provided a significantly higher level of nonlocal funding for education. While this policy would not prevent the migration of rural human resources to urban areas, it would decrease the transfer of rural investment in educational resources to urban areas. Urban areas capturing the value added would have made a greater share of the initial investment.

Urban dwellers often long for the values found in small-town America. Yet rural leaders may struggle to find the resources needed to survive.

Strategies for Revitalization

The most common strategies for fostering rural development are currently referred to as rural revitalization. They rely heavily on local initiative and resources and attempt to maximize the local ability to take advantage of opportunities to strengthen or "revitalize" the local community. The underlying philosophy of locally based development programs assumes that existing available resources are not used to their maximum, and that local human and material resources could be put to better use through improved leadership and organization. In addition, it is argued that local people should take charge of development — they know best what is locally possible and desirable, although they may need technical assistance to accomplish certain specific goals.

Locally initiated and supported development efforts are quite compatible with the notions of a free market economy: for example, enhancing local competitiveness, taking advantage of opportunities whenever they arise, and building community entrepreneurship. All these are regularly cited goals that strengthen local efforts through leadership development and technical assistance.

When competing for outside resources and attracting new employers, rural communities are especially disadvantaged. The local leadership in rural areas usually includes citizen volunteers and people with limited managerial experience. While the leadership in larger urban centers is able to rely on in-house technical assistance from civil engineers, planners, and those acquainted with social service delivery systems, these people and skills are largely absent in many rural areas. As a result, when local people come in contact with governmental agencies or large private employers, they frequently lack the technical skills to communicate with these "outsiders" or to provide them with the necessary information. Even when dealing with existing local businesses and employers (such as hospitals), rural leaders are frequently unable to comprehend issues and provide the necessary technical support. Consequently, much of the effort to strengthen local development efforts focuses on creating local leadership, providing technical assistance, and facilitating contact with the outside world. The RURAL PARTNERS®/Kellogg project described elsewhere in this issue is an excellent example of a carefully designed pilot effort to enhance local development capabilities of rural communities.

Locally based development efforts currently promise the best approach to rural revitalization. These efforts focus strongly on community self-help through better

More Than Brick, Cement, and Steel Projects

A three-year program is under way in 12 rural Illinois counties to support local leaders involved in revitalization efforts. Men and women from these counties are receiving training in leadership, conflict management, leadership recruitment, governmental relations, strategic planning, and a host of other skills necessary if local revitalization efforts are to succeed.

The program, "Helping Rural Communities Prepare for Economic Development," is sponsored by the University of Illinois Cooperative Extension Service, the W.K. Kellogg Foundation, and RURAL PARTNERS®, a coalition of more than 120 public and private organizations. It encompasses a fundamental principle for success — community and economic development efforts must not only be supported, but should actually be driven, by local leaders.

"These leaders will identify not only existing community leaders, but individuals who are likely to emerge as leaders in the coming years," explained Jerry Robinson, program leader. "Counties in this program will benefit as new leaders become active in development and planning.

"The program is designed to empower local citizens to create and manage change in their communities," he said. "Many research studies and our experiences in Illinois communities indicate that the involvement and participation of a dedicated group of local leaders is by far the most significant factor in stimulating economic change in a community."

Increased cooperation between the public and private sectors in the 12 counties is one of the program's goals. Counties involved in the RURAL PARTNERS®/ Kellogg effort are Carroll, Cass, Cumberland, Ford, Fulton, Hamilton, Henry, Macoupin, Pike, Saline, Shelby, and Wayne.

The 72 local County Development Coordinators are supported in their activities by eight to 12 hours per week of salary by their employers. Coordinators attend workshops taught by University of Illinois faculty and community and economic development practitioners from the private sector and government agencies.

Since its beginning in 1990, the RURAL PARTNERS®/Kellogg program has been recognized by the Illinois Chamber of Commerce as the primary program for statewide community development in rural Illinois, and has been formally endorsed by the Illinois Development Council.

"Rather than trying to re-invent the wheel, Helping Rural Communities Prepare for Economic Development emphasizes cooperation between public institutions such as the university and community colleges, public and private interests in the community, and statewide members of RURAL PARTNERS®," Robinson said.

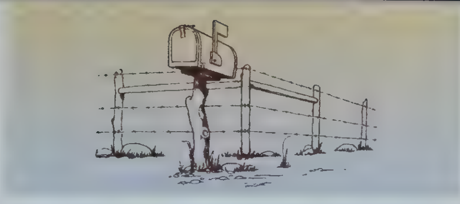
"This program can be adapted and extended throughout Illinois and will help make our state a national pacesetter in community and economic development. The most important thing, however, is recognizing that community development is done with local people, not to them. It is more than brick, cement, and steel projects. It works most effectively when and where local citizens determine and shape their destiny to the highest degree possible without depending primarily on outside resources." — *Information Services staff, Office of Agricultural Communications and Education*

organization of local resources, strengthened leadership, and enhanced local capacity-building. However, some limitations must be recognized. This approach, with its free market philosophy, frequently places rural communities in competition with one another on the assumption that the fittest communities will thrive. "Fittest" in this context appears to rely heavily on the ability of local people to provide strong leadership and marshal existing resources. However, even the best organized local development efforts, under the direction of strong, competent local leadership, may find that the needed resources cannot be obtained. Access to and availability of resources are determined by location, transportation systems, ability to provide telecommunications, or in some cases the skills of the local people.

Finally, those organizing locally based development efforts often assume that all community members will share equitably in the benefits. Research indicates that this rarely happens. Low-income, poorly educated, and elderly citizens in particular are frequently excluded from the benefits of locally based development efforts. Efforts must be made to ensure that all residents share in the benefits.

Currently, rural communities are called upon to assume nearly all the responsibility for mitigating the impact of major historical forces. Neither federal nor state decision-makers — up to this point — have allocated the needed resources for effective development and support of local initiatives. University of Illinois research and extension activities are geared to providing local communities with opportunities for leadership development and selective technical assistance. The university, working in collaboration with private and other public sector organizations, can contribute to strengthening the capacity of rural residents to make decisions about the futures of their communities.

John van Es, professor of rural sociology, Department of Agricultural Economics and program leader for Community and Economic Development, Cooperative Extension Service ■



Wanted: Allies for Rural Illinois

Bob Sampson

As a seer of Illinois political alignments, Paul Green may be unsurpassed. At the start of the 1980s, he accurately predicted the previously incongruous partnerships produced in the state legislature between Chicago Democrats and senators and representatives of that party elected from downstate districts once considered exclusively Republican.

Uniting these interests was a common opposition to those of the Chicago suburbs and collar counties that increasingly dominated the GOP.

"Rural Illinois and Chicago will find agreement in opposing the agenda of the suburbs and 'suburban creep,'" Green said then, referring to the steady physical growth of the suburbs and their increasing political power.

Looking to the 1990s, Green, director of the Institute for Public Policy at Governor's State University, sees an escalating atmosphere of challenge for rural Illinois — political and economical.

How Ya' Gonna Keep 'Em?

"How are you going to keep them down on the farm after they've seen Naperville?" quips Green, summing up the lure of suburban economic growth to rural youth faced with limited or no job opportunities in their home communities. "Rural Illinois is in a disadvantageous position," he says.

The author of several books and articles on Illinois politics and government — the latest *Restoration 1989: Chicago Elects a New Daley* — Green points out that it is impossible to talk about the future of any of Illinois' three major regions without examining the other two.

Chicago — one of the three — is dominated by three political-cultural facts, he notes. First, since the pre-Civil War decades, the city has always been different from the rest of the state in terms of its population numbers and varieties. Second, there is a lengthy history of the state's 101 other counties uniting in an attempt to politically isolate the city of Chicago by shortchanging it on congressional and legislative seats — an effort that was only defeated in the 1960s by the Supreme Court's one-man-one-vote ruling. Ironically, this judicial reprieve came just as the city was beginning to lose population.

"Finally, there is not a state in the union where the people living in its biggest city have less identification with the state as a whole than Chicago has with Illinois," Green says. "The University of Illinois is the state's major college, but the number-one college football team in Chicago is Notre Dame; in basketball, it's DePaul.

"When people from Chicago think about taking a vacation in the country to relax, they think of Wisconsin, Michigan, or Indiana. There is almost no identification with the rest of Illinois."

Suburban Chicago is the state's growth area in both political and economic terms.

"It is becoming a political entity. It has its own issues and needs," Green explains. "The original collar counties, such as DuPage and Lake, have grown so much that they now have their own suburbs — the ring around the collar. Counties such as Grundy, Kendall, Boone, and even Winnebago — whose biggest city, Rockford, calls itself a Chicago suburb — are examples of suburban growth."

While Chicago can still muster considerable political and economic power to defend its interests, and the suburbs continue to attract wealth and population, rural Illinois faces a different scenario.

"Rural Illinois needs all the allies it can get. While it is not disappearing, unless it gets some economic development, it will be unable to keep its young people," he predicts. "That's why the state needs big-ticket development projects to create the kind of revenue that can help spur growth in rural communities."

More than culture, economics, and politics separate rural Illinois from Chicago and the suburbs. In fact, there is no single rural Illinois. "Politically, there are at least four or five distinct areas in downstate Illinois," Green says. "Culturally, there are considerable differences between those living north and south of Interstate 70."

Some downstate counties such as Macon, Peoria, Rock Island, Madison, and St. Clair are more urban than rural and reliant on industry. Others, such as Champaign, Sangamon, and McLean, are also urban-influenced and more reliant on white-collar employment than agriculture.

"It is a common misconception in Chicago and the suburbs for people to think of the rest of the state as all farms. But the farm land is not really in southern Illinois, it is in the western, the central, and the northwestern parts of the state," says Green. "All the rural areas, farming and industrial, small town and small city alike, are in common need of one thing — jobs."

The new road to town, eagerly awaited by rural residents and businesses alike, is more often the road out of town, making it easier for local people to drive to bigger towns to shop.

That is why rural Illinois must find ways to gain and maintain allies in Springfield. As a separate political force, it has almost no power.

"Rural Illinois is literally losing its population muscle," says Green. "You can see this through the congressional reapportionment and state redistricting processes. In order to include the necessary number of people, some districts are so vast as to almost violate legal guidelines that they be compact and contiguous."

Jobs will help rural Illinois hold onto its future through its young people. Visualizing ultimate economic success in terms of landing a state prison is a self-defeating tactic, Green believes. Rural Illinois needs the type of jobs that offer the challenges, satisfactions, and, perhaps most importantly, the income levels that will allow people to live and raise families in comfort.

"Rural Illinois is being victimized by many things that combine to undermine its economy," says Green. "Ironically, two of them are the things that citizens in those communities have always wanted — roads and local control."

Charles Sellers Jr.'s recent book on pre-Civil War America, *The Market Revolution,* skillfully points out the double-edged impact of commercial development on early 19th Century Americans. Improved transportation brought new products and development that drove traditional craftsmen and trade relationships from the market. More than 150 years later, a similar process is being played out in Illinois.

"Communities have lobbied for interstates and four-lane highways for decades. But once they arrive, the smaller towns often find they simply make it easier for local people to drive to bigger towns to shop. They have driven out the mom-and-pop operations," he says. "The shopping malls of today are the street corners of yesterday.

"In a sense, the highways so desperately sought are helping to wreck small towns that once had a solid socio-economic base."

Shrinking tax bases and revenues have made local control an expensive tenet, especially in Illinois, which leads the nation in the number of government taxing bodies. "In many rural areas where everyone wants to keep the local school open, they don't have the economic or population base to provide the necessary services," Green says. "By shortchanging their young people, these communities put rural Illinois in a disadvantageous position.

"Leaving out the problem of school consolidation, however, Illinois has too many governments. We need to consolidate all these special districts and services into one of three governments — township, municipal, or county." A former township official, Green is not optimistic that this will happen.

"Local control is what everyone wants. Everyone wants the services of government, but nobody wants a tax increase to pay for them. In fact, people actually want taxes to decrease. Illinois is one of the few states that actually believes 'reform' means 'savings.' Seldom, though, do you have gain without pain."

As the 1990s proceed, Green believes that neither the multitude of government bodies nor the bureaucracy provide rural Illinois' severest challenge. "The real problem is we aren't producing enough revenue in this state through economic growth," he says. "If the jobs were there, a lot of these problems would take care of themselves."

For rural Illinois, then, the pressure for successful and meaningful economic development — in other words, jobs that pay a living wage — is more than desirable. It is essential.

Without it, for rural Illinois, Green fears, things "will only get worse."

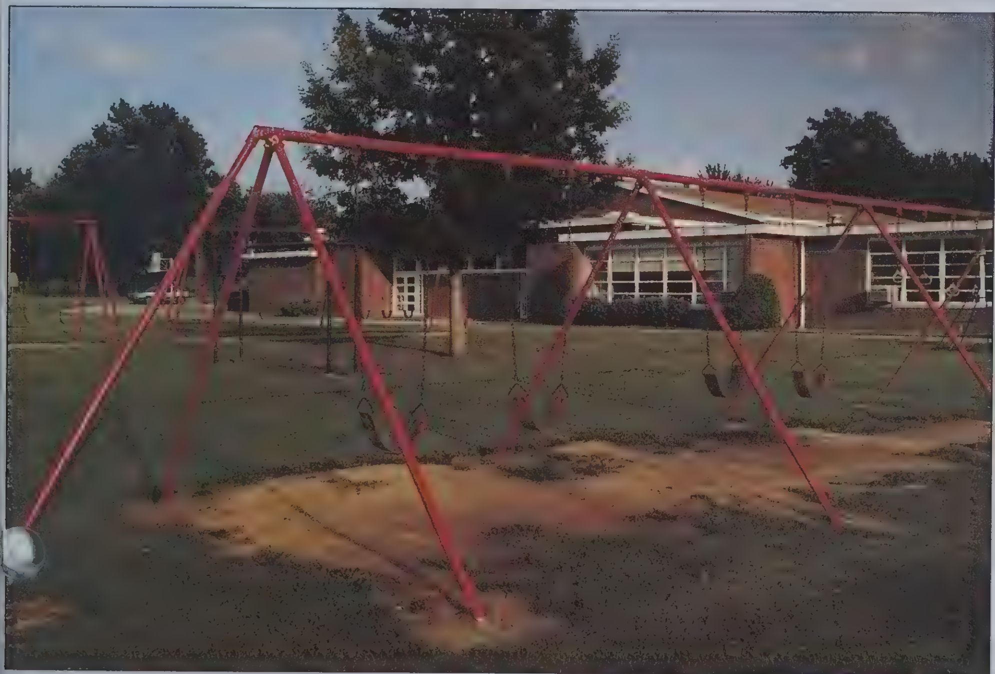
Bob Sampson, Extension communications specialist, Office of Agricultural Communications and Education, Information Services

Issues in Illinois Rural School Organization and Delivery

In my 1988 study of rural school districts in east central Illinois, *City Schools, Rural Schools,* I began with these words: "Conventional wisdom in education has held that small, rural school districts are a problem." I concluded that some were real problems and some were not. Although the same is true today, the number of rural school districts with problems seems to be growing. Areas of concern are (l) provision of an adequate education, (2) administrative competence, (3) low staff salaries, and (4) diverse student populations.

- **Provision of an adequate education**. Small elementary schools often produce excellent results, but in many rural communities it is difficult to maintain an adequate high school program. In small high schools, it is far more difficult to offer a sufficiently rich curriculum and to maintain a high-quality teaching staff in all the necessary subject areas. The demands of modern society for well-educated citizens outstrip the ability of many small high schools to provide the needed level of educational quality. A new approach to rural school organization is to create larger, rural school districts, possibly on a county or multicounty basis, with small community elementary schools and larger, regional high schools.
- **Administrative competence**. Small rural school administrative units create the need for many school superintendents, but they also create a job with so many varied requirements that few are qualified to do it well. A rural superintendent must be a business manager, a personnel expert, an instructional leader, a political wizard, a public relations genius, and often a building principal. It is unrealistic to expect one person to do all these things well. In larger school administrative units, various central office administrators can specialize in some of these functions, often resulting in better school management. It is not so much that many rural school administrators are not competent, but that they are asked to be experts in too many arenas.
- **Low staff salaries**. Teacher and administrator salaries in small, rural school districts are generally about 20 percent lower than in nearby towns and small cities. The per pupil costs in those districts are not necessarily low, which means that staff in small, rural schools often bear the costs of disproportionate economies of scale. Some personnel prefer to teach in small, rural districts; in fact, many are tied to the community through family connections. However, small, rural schools often have problems attracting and retaining high-quality teachers, especially in certain areas of specialization such as mathematics, science, special education, art, music, and foreign languages. Recent economic research has shown that good schools seem to be characterized by smaller classes and the ability to attract and retain good teachers, especially those who are experienced and have advanced degrees. Rural schools can offer the first, but not the second trait.
- **Diverse student populations**. Once upon a time, problems of poverty, drugs, single parents, teenage mothers, and domestic violence were thought to be almost exclusively urban problems. We now realize that these problems exist in rural communities as well and adversely affect schools. Many rural school districts are not prepared to deal effectively with these social problems, lacking both staff and resources.

These are just some of the problems facing rural school districts, their organization, and their ability to offer quality educational services. — *James Gordon Ward, associate dean and associate professor of educational administration, College of Education, University of Illinois at Urbana-Champaign*



Rural schools face many challenges as they try to offer quality education to a diverse student population. Low staff salaries and limited resources prove frustrating to teachers and students alike and have led to the creation of larger, rural school districts as a possible antidote.

In Progress

Tina M. Prow regularly contributes in-depth articles to *Illinois Research*. Her work was cited recently in international competition.

Honors for Science Writer Tina M. Prow

Tina M. Prow, *Illinois Research* science writer, recently earned top honors in international competition for her work as editor and writer of *Agro-Ecology News and Perspectives*. This newsletter received first-place recognition from Agricultural Communicators in Education (ACE) in the 1992 international critique and awards program and a Bronze Medal from CASE, the Council for Advancement and Support of Education. Prow, a contributor to *Illinois Research* for the past four years, previously worked for the Agricultural Experiment Station at New Mexico State University in Las Cruces.

Search for Control of Rampant Zebra Mussels

The invasion of zebra mussels in the Great Lakes region has raised multiple concerns by raw water users. The prolific reproductive rates of these mussels make them a major economic and environmental danger as they clog intake pipes of power and water treatment plants. Already, over the past five years, zebra mussels have cost the Great Lakes region millions of dollars for cleanup and control.

Zebra mussels also have seriously impacted the ecosystems of Lake Michigan and associated rivers and streams by destroying natural mussel populations and removing natural organisms in the water used by other aquatic life. Although cleaner water can occur when a colony of zebra mussels consumes large amounts of algae, aquatic weeds can then take over and have a negative effect on water quality.

Taking advantage of special funds from Congress, four Illinois-Indiana Sea Grant researchers were awarded grants totalling $338,107 to study effective control methods. The projects and principal investigators are:

- **Genetics of Zebra Mussels: Critical Data for Ecological Studies and Development of Effective Long-Term Control**

Strategies. Ellen Marsden (P.I.), Illinois Natural History Survey; Bernie May, Cornell University. ($102,113).

This study will determine if these mussels represent a single, genetically uniform population or multiple populations. Results could lead to development of effective, long-term control measures.

- **Osmoregulatory Physiology of the Zebra Mussel.** Robert L. Preston (P.I.), Illinois State University. ($150,000).

Zebra mussels have developed an unusual physiological capacity to deal with osmotic stress. Control agents that disrupt the cellular regulation of salt, water, and solute balance may provide effective control. This project will provide the necessary physiological data to select appropriate chemical and biological control agents.

- **An Investigation of the Larval Development and Shell Morphology of the Zebra Mussel, *Dreissena polymorpha*.** Gail Lima (P.I.), Illinois Wesleyan University. ($69,153).

This study will determine the maximum potential for larvae of this species to delay metamorphosis and prolong the larval dispersal period. Factors that influence growth and settlement (such as temperature and diet) will be examined. Results will (1) help predict the spread of this introduced species in freshwater systems and (2) aid in the development of appropriate control measures that interfere with the settlement and metamorphosis of the free-swimming larvae.

- **Carbon Dioxide as a Narcotizing Pre-treatment for Chemical Control of *Dreissena polymorpha*.** William J. Elzinga (P.I.), Environmental Science and Engineering, Inc. ($16,691).

Carbon dioxide may prove to be a feasible and environmentally safe alternative when compared with zebra mussel control options currently being used today. This study will determine the effectiveness of using carbon dioxide as a biocide and as a narcotizing pretreatment to chlorination. — *Robin Goettel, communications coordinator, Illinois-Indiana Sea Grant Program*

Suggested Reading

Further information about small towns and rural areas can be found in the following publications:

- "A Good Place to Live" by Philip Langdon. *Atlantic,* March, 1988.
- *Heartland* by James H. Madison. Bloomington, IN: Indiana University Press, 1988.
- *Late Harvest* by David R. Pichaske (ed.). New York: Paragon House, 1991.
- "Making Vivid Towns" by Jenny Young. *Small Town,* 22(November/December,1991).
- "Reviving Rural Life" by Joseph F. Coates, Jennifer Jarratt, and Lara Ragunas. *The Futurist,* 26(March-April, 1922).
- "The Second Coming of the American Small Town" by Andres Duany and Elizabeth Plater-Zyberk. *The Wilson Quarterly,* 16 (Winter, 1992).
- *Small Town America* by Richard Lingeman. New York: 1980.
- "Small-Town Blues" by Richard Hornik. *Time,* March 27, 1989.
- "Small Town Renewal" by Burt E. Swanson. *Journal of Rural Studies,* 1(No. 2, 1985).
- "Small Town Triage: A Rural Settlement Policy for the American Midwest" by Thomas L. Daniels and Mark B. Lapping. *Journal of Rural Studies,* 3(No. 3, 1987).
- "The Suburban Century Begins" by William Schneider. *Atlantic,* July 1922.
- "Where Breakdown and Bankruptcy Play." *The Economist.* November 2, 1991:21-23.

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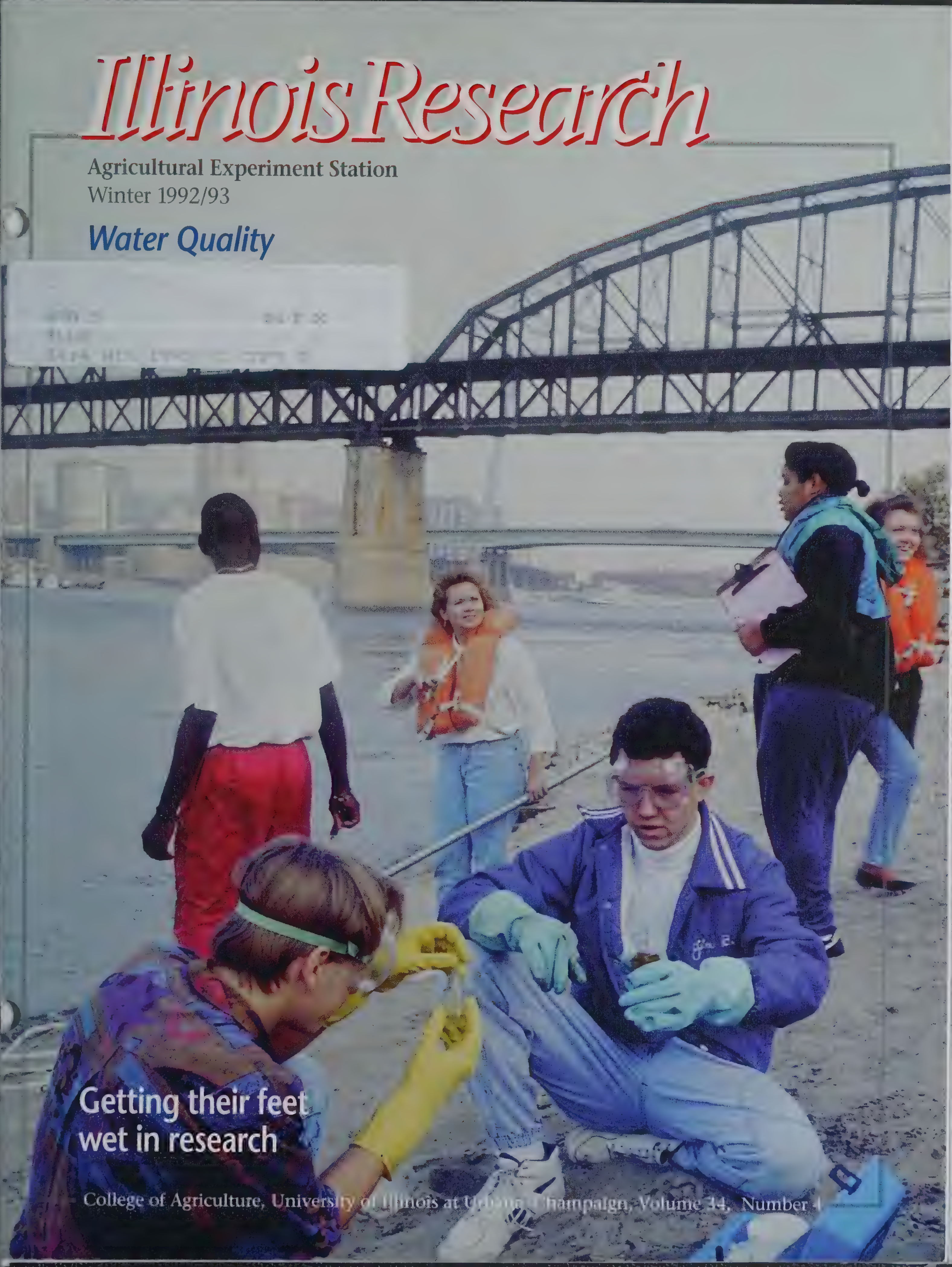
Water Quality



Getting their feet wet in research

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 34, Number 4

The Cover

Students take to the water for an adventure in science. A science class from Cahokia High School monitors water quality in the Mississippi River as part of the Illinois Rivers Project. *See page 16.*

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Water Quality

Showered with Challenges in Water Research

Water quality is not a new research initiative in our state. Scientists at the University of Illinois, other Illinois colleges and universities, the state scientific surveys (water, geological, and natural history), and state and federal agencies have all collected research and monitoring data for decades. What is new is the research emphasis.

In the past, researchers have focused largely on sediment or nutrient degradation of our water resources and on basic mechanisms of soil, sediment, and nutrient movement. Crop production maintenance was an underlying goal of soil conservation efforts, from which water-quality benefits were derived.

Now our efforts focus on the resources themselves, both surface water and groundwater, partly because of the growing number of contaminants that threaten them — including herbicides, insecticides, industrial solvents, and petroleum products.

Conserving our water resources is a complex problem, and its very complexity leads to numerous and sometimes conflicting objectives. Researchers at UI and elsewhere have had to reevaluate the context in which we work and the needs of the clientele we serve. How should we tackle the problem? Can change occur through education and volunteer compliance with guidelines derived from our research? Or must we as a society regulate industries using and affecting our water resources?

Water-quality research in the past and in the present helps us frame new questions to ask, but it cannot provide the complete answer. All of our research and monitoring gives us only a partial view of the problems, the processes, and especially the interactions within the overall water-quality picture.

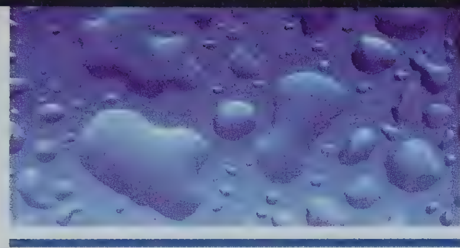
For a more complete view of water quality, we need to take a new approach, a "systems" approach. With new tools for research and planning, such as Geographical Information Systems (GIS) databases, researchers have access to more pertinent information in much more detail than ever before. With these new tools, researchers can examine many pieces of information from throughout a watershed to highlight the problem areas so that research and education dollars can be focused where they will have the most impact. Existing computer models are being modified and new models developed to take full advantage of the power of GIS.

All of this points to a real need. Research that examines a natural system requires good information not only about the system's components but also about the interactions among individual processes. Computer models are only as good as the data used to construct and evaluate them — the models must accurately represent the processes and interactions found in a natural system. If we are to increase our understanding of our water resources and develop intelligent, fair methods to protect those resources, we must always keep the "big picture" in mind while interpreting data on the details.

An obstacle in the path of water-quality protection is a growing scarcity of research dollars emphasizing basic data collection, especially for surface water. That scarcity can be overcome by educating the funding organizations — federal agencies and private foundations — about the importance of basic data collection and by doing important, enlightening research with the data we have at hand.

The challenge of fully understanding our water resources is great, but we must undertake it. — *Michael C. Hirschi, associate professor, Department of Agricultural Engineering, and water-quality program coordinator, Cooperative Extension Service*

Michael Hirschi checks out the rain simulator in the Department of Agricultural Engineering.



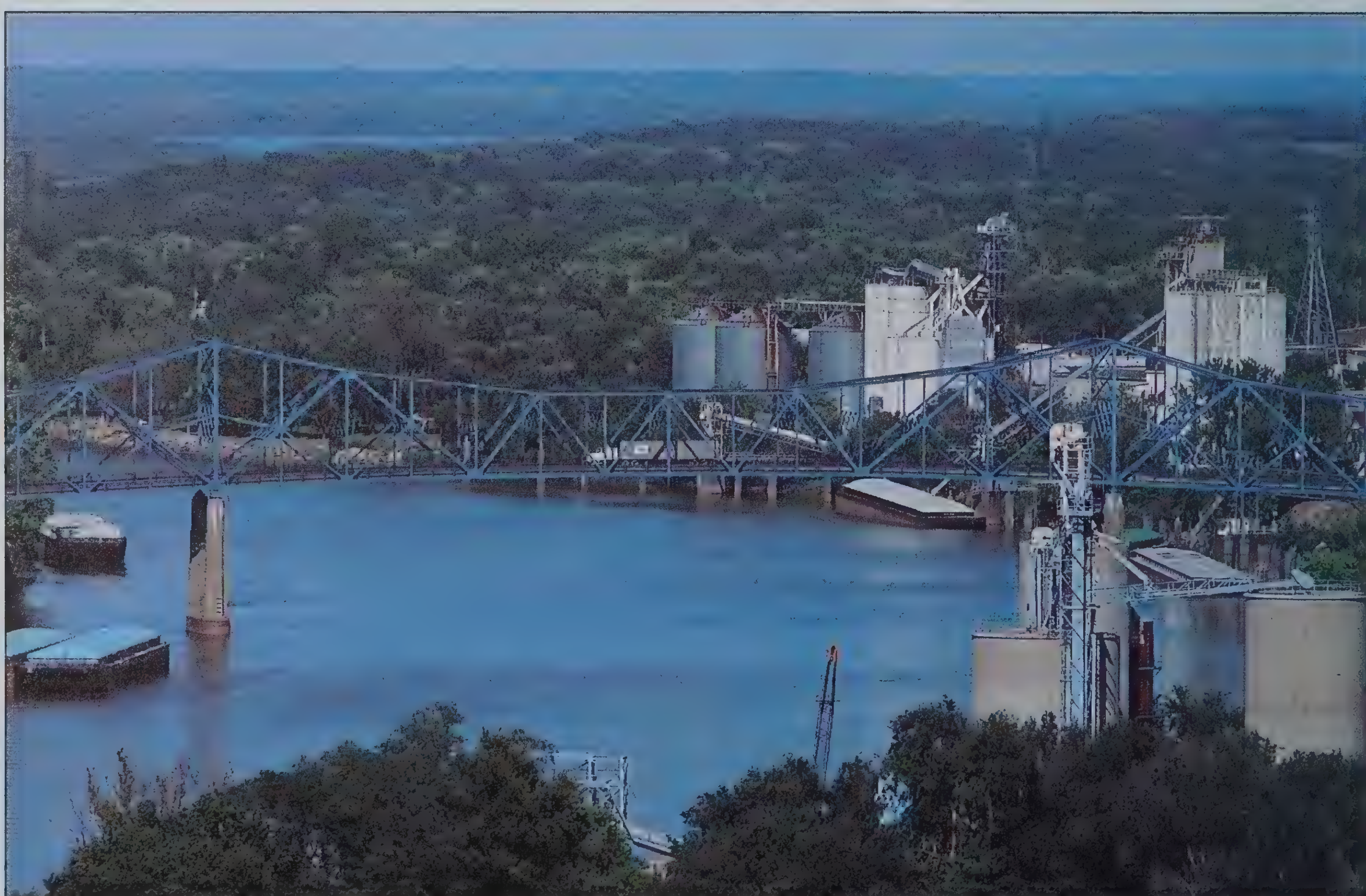
Measuring Water Quality

Allan S. Felsot

Concerns about water quality are not new, but they are more widespread than ever before. Newspapers frequently grab our attention with headlines about government-sponsored well testing or threatened public water supplies. Because of the complexity of water-quality issues, however, the media can offer little more than superficial glances that often seem to confuse rather than to enlighten.

Even experts disagree about the safety of our water resources. Chemists can measure with a high degree of sensitivity and accuracy a plethora of chemicals in every component of our environment, but they do not always agree on how much of a particular chemical in our water supplies constitutes a risk.

Part of the problem is that our biological understanding of the effects of exposure to extremely small amounts of chemicals lags significantly behind our ability to measure them. But there is another vital piece of the puzzle too often ignored in media accounts of environmental pollution — how we measure and study water quality.



Barges and grain elevators along the Illinois River at Havana reflect the river's use for commerce. Like many of the state's rivers, the Illinois also provides wildlife habitat and water for municipalities.

What Is Water Quality?

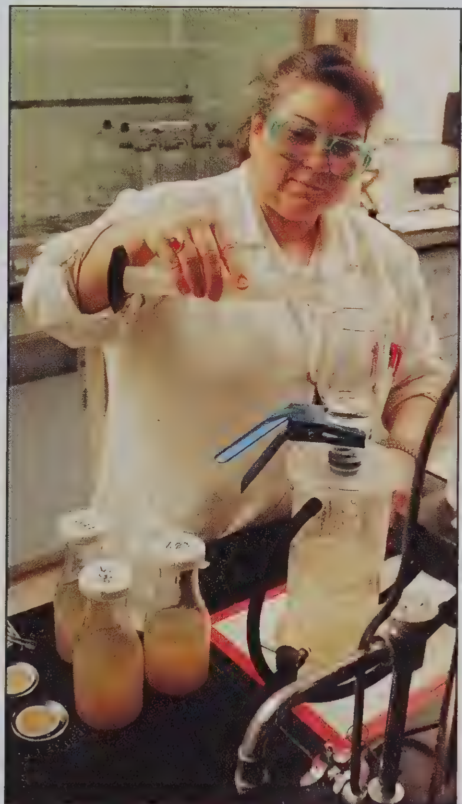
Assessing water quality is much more complex than dropping a water sample in one end of a machine that spits out a number at the other end. Water quality is not an absolute measure of the cleanliness of water; it can range from acceptable to unacceptable depending on the intended use of the water supply. For example, water intended for drinking has to meet safety criteria that protect human health and provide acceptable taste.

Water quality is the sum of physical, chemical, and biological characteristics of surface water (streams, rivers, and lakes) and groundwater (aquifers). Characteristics that are measured include microbial contamination, inorganic chemicals, organic chemicals, radionuclides, total dissolved solids, turbidity, corrosivity, color, odor, and taste.

Laws to protect water resources and maintain good quality have been passed and amended numerous times during the past forty years. These laws also provide a basis for assessing water quality through regulatory monitoring and research. The Federal Water Pollution Control Act was passed in 1948, and its most well-known amendment was the Clean Water Act of 1972. In addition to regulating pollutant discharges into navigable waters and providing construction grants for municipal wastewater treatment plants, the CWA also required the U.S. Environmental Protection Agency to conduct extensive research on water pollution and its management. The maximum contaminant levels set by the Safe Drinking Water Act, the environmental impact statements required by the National Environmental Policy Act, and groundwater monitoring systems necessitated by the Resource Conservation and Recovery Act all stimulated intense research on every aspect of water quality.

Conducting Water Research

The main elements of a water-quality study can be divided into several processes: problem definition, experimental design, quality control and assurance plan, site characterization, sampling, analysis, and data handling and interpretation. As with any experiment, the problem to be addressed must be defined, and objectives or hypotheses must be developed. In the case of water, there are essentially two modes of investigation — monitoring for regulatory purposes and monitoring for research and long-range planning. The design of the study, which includes definition of the target water resources, will depend directly on the objectives of the investigation. Regulatory monitoring, for example, is needed for enforcement of health standards or to determine the source of polluting discharges. Monitoring by research institutions tends to focus on fundamental processes affecting movement of chemicals to groundwater or surface water, the dynamics of concentrations and loads over time in relation to specific agricultural practices or landforms, or general trends in water quality. Regulatory agencies may also engage in more research-oriented problems; for example, the Illinois EPA has been monitoring the annual trends in concentrations of nitrates and pesticide residues in rivers.



Laboratory research is a critical component of assessing water quality. Saada Hamdy, a chemist with the State Water Survey, measures total suspended solids and volatile suspended solids in samples from Lake Pittsfield watershed in western Illinois.

Water quality is the sum of physical, chemical, and biological characteristics of surface water (streams, rivers, and lakes) and groundwater (aquifers).

Accurately measuring water-quality parameters is difficult; error stems from two sources — inability to accurately sample the environment because of its complexity in space and time, and unavoidable biases during the laboratory analyses. Once the objectives of a water-quality study are well defined and the target water resources delineated, a quality control and assurance plan must be developed to ensure that all samplings and analyses are conducted with maximum precision, accuracy, and completeness. Quality control procedures apply to all aspects of the water quality assessment, from site characterization and sampling to laboratory analyses and final interpretation of the data.

Site Characterization and Sampling

Site characterization is necessary to aid interpretation of the abundance of data that will be generated in typical water-quality research and monitoring programs. Site characterization during the planning stages of a study is also critical for determining the number and frequency of samples that will be collected and the type of sampling equipment to be used. For example, if determination of nitrate loading in a river is the objec-

tive, then the flow rate of the river must be characterized. If the width and depth of the river basin and the current flow are accurately measured, then the volume of water moving past a sampling point per unit time can be calculated and multiplied by the concentration of nitrates to determine mass of nitrates moving into the river from all points upstream of the flow measurements. The accuracy of determining the mass of nitrates, however, will be greatly improved if frequent samples are taken. Thus, a researcher would probably use an automated sampler and stage recorder to acquire continuous measurements over long periods of time.

If groundwater is to be studied, then sampling points will include either existing wells or a cluster of new drilled wells (monitoring wells). Because contaminants migrate through the unsaturated zone of the soil (the layer of soil where pores are not fully filled with water) before reaching the water table (the saturated zone where all soil pores are filled with water), characterization of the soil is essential. Important properties include soil texture, permeability, organic carbon content, and depth to water table. Assessment of the region around the well is essential to determine the direction of groundwater flow and the location of

Chemical Toxicity: More Than a Numbers Game

Understanding data on chemicals and their toxicity is quite a challenge. A fraction of one part per billion (ppb) of atrazine in water or one part per million (ppm) of malathion in wheat flour is not easy to visualize or appreciate. Amidst the technology and the emotions surrounding the issue of chemical toxicity, there are, however, some commonsense steps to understanding the health-related risks associated with low concentrations of pesticides.

Let's start with some important facts. Many pesticides are toxic to a wide range of organisms, including humans. Although we call them insecticides, herbicides, or fungicides, these chemicals do not act exclusively on insects, weeds, or fungi. Additionally, although we describe pesticides by such primary physiological effects as the inhibition of nerve impulse transmission or plant growth, we know that at least some also enter into other biochemical reactions and exert adverse effects.

After we acknowledge that pesticides can injure humans, we face more difficult questions about the risks of adverse health effects if humans encounter only extremely low doses. Confronting the risks of chronic low doses of toxins requires that we abandon generalized arguments about the "negligible" nature of low concentrations. These arguments include analogies that are intended to be comforting by stressing smallness: 1 ppm is, after all, the equivalent of only 1 inch in 16 miles, and 1 part per billion (ppb) is the same as 2 seconds in a lifetime.

Other analogies, however, tell a different story. Donald Mackay of the Institute for Environmental Studies at the University of Toronto points out that only 30 parts per trillion of vitamin B-12 means the difference between good health and deficiency illness; DNA represents only 1 ppb of the weight of an adult human, yet it controls all physiological activity. In agriculture, we know that many pesticides exert their effects when applied at rates that result in residues of 1 ppm or less in target environments. Quite obviously there is no universally negligible concentration for chemicals, and arbitrarily trivializing the possible risks of low concentrations is inappropriate.

Because specific compounds, whether natural or synthetic, are biologically active even at extremely low concentrations, studies to determine the health effects of low doses of pesticides have shifted from traditional short-term dose-response experiments to risk assessment studies that focus on chronic effects. Such studies have become especially important in efforts to determine carcinogenicity, the ability of a chemical to cause cancer.

A standard approach to identifying carcinogens is to administer relatively high doses of a substance to laboratory animals for their entire lifetimes and then sacrifice them to check for tumors. Proponents argue that such an approach is necessary for detecting rare cancers, and that high doses simply increase the odds that the chemical will come into contact with a susceptible site and exert its effect even though only a relatively small number of animals can be tested. Critics argue that the high doses have direct toxic effects, triggering additional processes that result in cancer; they contend that the much lower doses encountered by human consumers would not trigger the same sequence or cause any cancers.

So which of the opposing views is correct? Although books have been written supporting each of these argu-

sources of possible contaminants. Background concentrations of contaminants in soil water within the unsaturated zone can be collected using pressure-vacuum or suction lysimeters. Such sampling can serve as an early warning sign for migration of contaminants from the soil surface to the water table.

If an existing well is sampled, then water can be collected at the resident tap. Water should be run for several minutes through the tap before collection. This procedure flushes out the well, pump, and lines to ensure that the sample is representative of the groundwater around the well and not the artificial conditions within the well or distribution system. When monitoring wells are used, they are usually sampled directly by a hand-operated bailer or a pump. In this case, standing water must first be bailed out and "fresh" water allowed to enter into the well; water collected after the well has recharged will be more representative of the true condition of the groundwater.

The type of sampling equipment used must be chosen to preserve the ambient environmental conditions as closely as possible and to avoid introducing new contaminants. For example, if a well is to be sampled for bacterial pollution, then the sampling device must be sterile.

ments, it remains difficult to reach broad conclusions. One can, however, reject the extremes. Available data do not support unequivocal predictions of thousands of cancers or deaths as a result of the consumption of Alar-treated apples by children. Conversely, an understanding of cancer research also precludes conclusions that cancers will occur in humans only if they consume the same (high) doses of chemicals that were fed to laboratory animals.

Rejecting the extremes does not mean that agriculture or the public must be paralyzed by indecision. Risk management is and should be ongoing even though risk assessments are incomplete. In the simplest form of risk management, pesticide uses have long been regulated to avoid residues that exceed established tolerances; future use patterns will certainly be limited to avoid violations of maximum contaminant levels (MCLs) and health advisory levels (HALs) in water. Yet simply prohibiting excessive residues or contamination levels does not represent a comprehensive approach to risk management, especially when the validity of MCLs, tolerances, and similar values is disputed.

As risk management focuses on such broad actions as banning pesticides or revamping farming practices, the concept of "relative risk" is fundamental. How much risk does a pesticide residue pose in comparison to other risks? Many often-cited comparative risks — for example, the risks associated with automobile travel or a walk in the park — are meaningless because they are not linked in any way to the risks of exposures to pesticides. Relative risks that are relevant include those associated with other pest management practices (for example, alternative pesticides, whether natural or synthetic) and the toxic effects of insects, bacteria, fungi, or weeds that may contaminate foods or water.

Because pesticides play crucial as well as cosmetic roles in the production of many fruits and vegetables, as well as other crops, wholesale cancellation of pesticide registrations certainly would affect the availability, price, and quality of fresh produce (although the magnitude and duration of such effects may be disputed). Because fresh produce contributes to good health, it is legitimate to propose that over-regulation of essential uses of pesticides poses a risk to human health. Consequently, as regulations are employed as tools of risk management, we all need to remember that alternatives to current practices also pose risks.

In risk management, the challenge facing agriculture as a whole is to react responsibly — not just defensively — to concerns about pesticides. To do so, we must establish the shared goal that food and water carry no added chemical risks.

We must recognize that if specific pesticides commonly show up in water supplies, persist in the environment, or regularly remain as residues on foods, the pesticides probably pose unwanted risks even if their specific impacts on health are ill-defined. Unless such chemicals are absolutely essential to food production or are clearly safer than available alternatives, their futures should be limited. To replace these compounds, the development and use of "better" pesticides — those that are more selective to specific pests, less toxic to nontarget organisms, and less persistent in the environment — must continue. Just as importantly, we need to accelerate the adoption of truly integrated pest management practices that include pest-limiting production systems, pest scouting, and the selection of pest control methods by a process that includes consideration of health and environmental risks.

The current bottom line in this yet unfinished story is that although risk assessment has not generated definitive answers about the health risks from low concentrations of most pesticides, risk management still can proceed in a prudent manner. — *Rick Weinzierl, associate professor, Office of Agricultural Entomology*

Water in deep wells may be deficient in oxygen, and precautions must be taken to avoid introducing air into a sample.

When analyzing for metals, sampling devices and storage containers must be made of plastic to avoid contaminating the water with dissolved metal ions from the container walls. Teflon samplers and glass storage bottles are recommended for avoiding adsorption of organic compounds on container walls or leaching of plasticizers into the water. If volatile organic compounds will be measured, the storage bottle must be air-tight.

After collecting the sample, the researcher must store it in a condition that will not allow further deterioration or alteration of its characteristics or components. Usually water samples are held in refrigerators or freezers. Every attempt must be made to analyze the samples as quickly as possible; for many samples, a two-week holding period is permissible. Depending on the constituents to be analyzed, a preservative can be added to maintain the integrity of the sample by inhibiting microbial activity or stabilizing the pH at an optimum level.

What Is Government Doing to Protect Our Water?

Current government programs for water-quality protection date back to 1972. The Federal Water Pollution Control Act Amendments of that year declared the goal of attaining water of a quality suitable for "the protection and propagation of fish, shellfish and wildlife, recreation in and on the water, and agricultural, industrial, and other purposes including navigation." These uses were to be achieved by 1983. By 1985, all discharges of water pollutants were to be eliminated.

In the interim, the 1972 Amendments required states to develop water-quality management plans that included use classification of water bodies, water-quality standards for each use class, and effluent standards for dischargers. The effluent standards are based on available pollution-control technologies. Those standards were incorporated into discharge permits for municipal and industrial sources of pollution. To help municipalities comply with the new effluent standards, the federal government has provided grants for sewage treatment plant upgrades.

Although point sources (identifiable, fixed locations, such as chemical plants) are subject to discharge permits, nonpoint sources (diffuse locations, such as agricultural runoff) have no similar requirements. The law calls for the application of "best management practices" as part of state water-quality management plans, but no specific guidelines exist.

Further amendments in 1977, 1981, and 1987 refined the basic approach taken in 1972. After several postponements, the zero-discharge timetable is no longer taken very seriously. The municipal sewage treatment program has switched from grants to loans administered by states. The list of regulated substances, which initially included a small group of "conventional" pollutants, such as nutrients and sediment, has grown to include many additional substances, especially toxic compounds. And, following studies in the 1980s that documented the widespread importance of nonpoint-source pollution, states are being pressed harder to come up with effective management plans.

Several other federal environmental laws intersect with the Water Pollution Control Act. The Superfund law (Comprehensive Environmental Response, Compensation, and Liability Act) is used to clean up hazardous waste dumps that, in many cases, are contaminating aquifers or surface-water sources. Even small dumps of mostly empty pesticide containers can be subject to CERCLA rules. The Federal Insecticide, Fungicide, and Rodenticide Act requires stringent review of potential environmental effects prior to the approval of new pesticides.

Environmental Analysis in the Laboratory

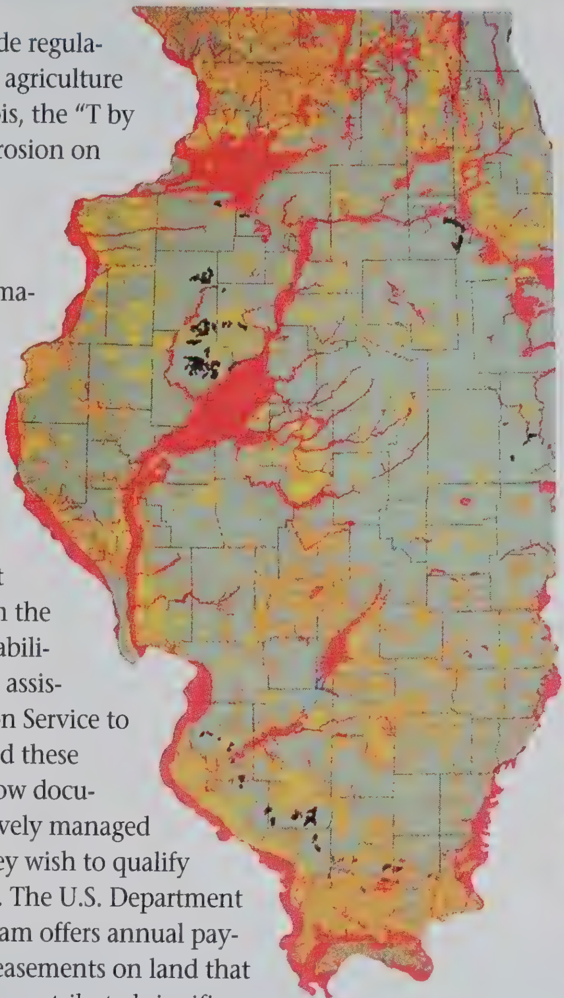
When returned to the laboratory, water is analyzed by methods chosen to provide known levels of precision (repeatability of results) and accuracy (nearness to a true value). Analysis usually consists of sample preparation followed by extraction and instrumental analysis and interpretation. If sediment or substantial amounts of particulate matter occur in the water, filtration may be required. The method of extraction depends on the nature of the sample. For example, pesticides are usually extracted with organic solvents that will not mix with water. The organic solvent, called the extract, is then concentrated to a small volume before instrumental analysis. If water contains large amounts of dissolved organic matter, usually indicated by a brownish cloudiness, the extract may have to be cleaned to remove compounds that would interfere with instrumental analysis.

During the past decade, new extraction methods have been developed to minimize the use of organic solvents, which are usually hazardous and must be used with proper ventilation. For example, solid phase extraction passes a water sample through a special solid matrix to which the pesticide adheres. The matrix is then washed with a few milliliters of organic solvent. Solid phase extraction also has the benefit of removing much of the dissolved organic matter from the water. The newest method for analyzing pesticides —

Apart from hazardous waste and pesticide regulations, the programs most directly affecting agriculture are operated by state government. In Illinois, the "T by 2000" law requires by the year 2000 that erosion on Illinois farmland be held below "tolerable" limits established by the Soil Conservation Service. "Tolerable" erosion refers to the amount of soil loss that is offset by the formation of new soil. Illinois law also requires bulk agricultural chemicals to be stored and distributed well away from groundwater recharge zones.

Perhaps more consequential at this time are programs that encourage rather than require rural landowners to reduce pollution. Land management practices that will protect water quality are emphasized in the cost-sharing program of the Agricultural Stabilization and Conservation Service. Technical assistance is available from the Soil Conservation Service to plan and implement these practices. Beyond these long-established programs, farmers must now document that erodible land is being conservatively managed and that wetlands are being protected if they wish to qualify for federal crop support and loan programs. The U.S. Department of Agriculture's Conservation Reserve Program offers annual payments to landowners in return for 10-year easements on land that is highly erodible, adjacent to water, or that contributed significantly to water quality or wildlife impairment.

In concert with its "T by 2000" program, Illinois shares the costs of changing land management practices in ways that diminish erosion and improve water quality. The state's budget for these programs was $500,000 in fiscal 1992, and no money was allocated for fiscal 1993 — far below the $20 million or more put into similar programs each year by other midwestern states. The funds have been split between direct cost-sharing with individual landowners and allocations to watersheds with special water-quality problems. Further information on water-quality laws and programs in Illinois can be obtained from the Illinois Environmental Protection Agency and the Division of Natural Resources of the Illinois Department of Agriculture. Soil and Water Conservation Districts, located in each county in Illinois, are a local source of information. — *John B. Braden, professor, Department of Agricultural Economics*



Potential for Agricultural Chemical Contamination of Aquifers in Illinois

- Aquifer material within 5 feet of land surface
- Aquifer material between 5 and 20 feet of land surface
- Aquifer material between 20 and 50 feet of land surface
- No aquifer materials within 50 feet of land surface
- Lake
- Disturbed land (for example, surface mines)

As indicated by the large areas of red, the regions most at risk are the Green River lowlands (farthest north) and Mason County (see article on page 26).

Source: Dennis P. McKenna and Donald A. Keefer, Illinois State Geological Survey, 1991.

enzyme-linked immunosorbent assay (ELISA) — relies on kits produced by the biotechnology industry that are extremely specific and sensitive for a single pesticide. ELISA generally allows the analysis of pesticides directly in water without prior preparation.

The type of instrumentation chosen for analysis also varies with the nature of the sample. Pesticides are most commonly analyzed by gas-liquid chromatographs after extraction with organic solvents; less frequently, a high-pressure liquid chromatograph will be used for special types of pesticides, but extraction may not be required first. Inorganic substances such as nitrate can usually be analyzed directly without prior extraction or preparation. Inorganic compounds may be measured indirectly by visible light spectrophotometry after reaction with a color reagent or directly by ion chromatography. Heavy metals may be analyzed directly by atomic absorption

Water-quality parameters change over space and time. Taking one water sample from a river is like taking a single photograph of a horse race.

spectrophotometry and plasma emission spectrometry. Regardless of the specific instrumentation, all equipment must be calibrated daily using known concentrations of the substances being analyzed.

Organic contaminants pose a special problem in water-quality studies because the chromatographic detection methods used routinely for their analyses only provide tentative identification of their identities. A water sample may contain hundreds of naturally occurring organic chemicals that can interfere with the analysis of the substances of interest; therefore, the identity of an organic compound must be confirmed using an alternative chromatographic method or preferably a technique known as mass spectrometry. Mass spectrometry provides the highest level of confirmation of identity by providing the molecular weight of the substance being analyzed and a spectrum from which the molecular structure can be deduced.

In addition to chemical or physical analyses, water quality can be assessed using biological assays. For example, the toxicity of treated wastewater can be determined by exposing various sensitive indicator organisms to the collected samples. One of the most commonly used organisms is a crustacean called Daphnia. Rather than satisfying a numeric water-quality standard, where a specific chemical concentration must not be violated, toxicity tests can satisfy narrative standards that describe a characteristic or property of the water. Narrative standards are also used to regulate odor and taste of drinking water.

Once water samples are returned to the laboratory, analytical accuracy depends on a well-defined quality control plan. Such a plan includes several processes for defining systematic errors during preparation and instrumental analyses of a sample; a quality control plan should be operational before sampling even commences. And quality control procedures must be stringent to meet EPA standards.

Checking the Data

After analyzing a water sample, a researcher or regulator must determine the validity of the number produced by the laboratory. He or she must be sure that a quality control plan was followed. In many laboratories, mass spectrometry is not routinely used to provide positive confirmation of chemical identity; in other cases, mass spectrometers commonly used as detectors on gas chromatographs may not be sensitive enough to detect the extremely low concentrations of organic contaminants. In this situation, the researcher should be wary of "false positives" — mistakenly concluding that a contaminant is present when it is not.

The changing nature of water-quality parameters over space and time casts uncertainty into conclusions based on a limited monitoring program. Taking one water sample from a river is like taking a single photograph of a horse race. When monitoring for regulatory purposes, specifically defined numeric standards are applied to a limited set of water samples for detection of violations. Yet all measurements have a degree of error, and the true value can never be known. The recently amended Safe Drinking Water Act handles this uncertainty by requiring action if the average of four successive samplings show violation of the standards.

Any sampling program will fail to capture the complete picture if the area being studied is a large watershed or perhaps one of the Great Lakes. In other cases, enough samples cannot be collected to definitively determine the source of pollution. Use of advanced geostatistical techniques, however, can fill in the gaps to help interpret the dynamics of specific water-quality parameters for unsampled areas.

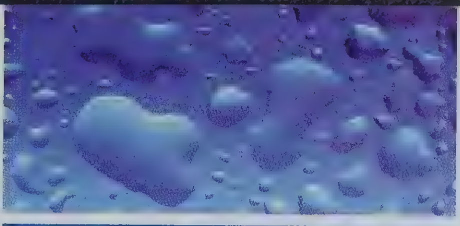
Experience makes a good teacher, and sharing data bases of water quality among different regions of the country is important in environmental monitoring and assessment programs. WATSTORE, which is maintained by the U.S. Geological Survey, and STORET, which is maintained by the U.S. EPA, archive water quality data taken across the United States. These data bases are good sources of historical changes in water quality. Such knowledge can be useful for assessing long-term trends in water quality and for serving as a signal about deteriorations or improvements as the result of changes in law.

What the Data Mean

Mathematical models for predicting transport of chemicals into surface water or groundwater are increasingly being used to assess management practices that might improve water quality. Water-quality monitoring helps farmers make wise decisions about soil, crop, and chemical management practices. Water-quality data is also useful for conducting risk assessments about new chemicals or industrial processes so that adverse consequences to human health or ecological integrity can be predicted and avoided.

Water-quality monitoring is necessary to meet the demands of laws passed to protect our water resources. As we learn more about the mechanisms underlying the dynamics of water quality, we will be better able to predict changes brought about by human activity or natural processes.

Allan S. Felsot, Center for Economic Entomology, Illinois Natural History Survey (currently with the Department of Crop and Soil Sciences, Washington State University)



Learning to Manage Our Water Resources

Glenn E. Stout and Holly B. Korab

Five decades ago, there was a major push in the United States to build large dams across hundreds of rivers throughout the nation. The dams were promoted as a way to improve navigation and to create vast reservoirs that would supply water for cities and industry, and supplement irrigation for agriculture.

Information on how to design and construct the dams was readily available. What was lacking, however, was specific information on the subsequent impacts of the developments.

Virtually no research had been done on how to manage these resources once they were created. Nor had there been many studies of the effects of soil erosion and pollutant runoff on the life span of the reservoirs or the quality of the water. In fact, other than how to build them, the nation knew little else about dams.

This oversight did not stop dams from being built, but it did create a furor. Universities throughout the country insisted that the federal government create a water research program to investigate all aspects of water resources issues — technical, biological, sociological, and economic — so that the nation could manage its water resources wisely.

Building Reservoirs of Knowledge

In 1963, the University of Illinois created the Water Resources Center in anticipation of a federal law passed the following year establishing water research centers at land-grant universities throughout the United States and its territories. The centers were created to support interdisciplinary research and education in water resources conservation and management by drawing upon the intellectual talent and educational resources of state colleges and universities.

Although the centers are situated at the land-grant university in each state, their programs are open to researchers at colleges and universities across the state. Each center operates under the purview of the U.S. Geological Survey but establishes its own research priorities based on the needs of the state. Initially the Illinois Water Resources Center was lo-

U.S. Army Corps of Engineers

The information and technology needed to build dams was available before information was available about how to manage the new resource. To help fill the information void, the University of Illinois created the Water Resources Center. Pictured is Lake Shelbyville in central Illinois.

Illinois Soil Conservation

Sedimentation and periodically unsafe nitrate levels threaten Lake Decatur in central Illinois. The reservoir has lost one-third of its storage capacity to sedimentation since its construction in 1922.

cated in the UI Graduate College, but in 1972 it was assimilated into the newly formed Institute for Environmental Studies.

Focus on Farms

In Illinois, agriculture — not dams — has been the major focus of the state's water center. In fact, one of the center's first studies was of nitrates. Nitrates, chemical forms of the essential plant nutrient ammonia, were showing up in private wells in quantities that were being linked with several human health risks. Many scientists suspected that increased fertilizer use was the source of the nitrates, but little data existed to substantiate their concerns. Nor was there much data about nitrates in water wells.

This scarcity of data about a potential water hazard in Illinois was exactly the kind of problem the center was established to deal with. Through the years, it has funded many studies on the sources of nitrates and their impact on water quality and human health.

During twenty-nine years of operation, the center has supported hundreds of projects, nearly two-thirds of which have been related to agriculture. This emphasis on agricultural studies reflects agriculture's predominance as the state's largest industry and its enormous impact on the state's water resources.

In the 1970s, a priority for the Water Resources Center was assisting agriculture in maximizing its production through water management, such as irrigation. Rainfall in Illinois is adequate for crop production, but its distribution varies considerably from year to year and from season to season. Research by the faculty in the UI College of Agriculture demonstrated that 1 to 8 inches of water are often needed during a growing season to maximize the crop yields and economic benefits. Construction of small lakes to provide the required water for supplemental irrigation where groundwater is limited was also found to be an economically sound practice.

The Lake Paradise study has inspired other communities to use lake sediments as a soil supplement.

Because many lakes in Illinois are constructed to supply communities with water, a decline in water capacity is a serious problem.

In the 1980s, attention shifted to soil erosion from farmlands and the resultant sedimentation of lakes. Rates of soil erosion of up to 2 percent per year have been measured in Illinois. When soil erodes into lakes at this rate, the storage capacity of the lakes rapidly declines. Because many lakes in Illinois are constructed to supply communities with water, a decline in water capacity is a serious problem. Communities are forced either to build new lakes or to pay for expensive and regular dredging. And dredging leaves communities with mounds of sediment to recycle.

The Costs of Sedimentation in Paradise

Lake Paradise in Mattoon is an example of a water-supply lake that in the 1980s was no longer serving the purpose for which it was designed. Sedimentation had decreased its storage capacity by 70 percent, and the town was forced to construct a costly new lake.

In 1982, the Water Resources Center organized and managed a research program at Lake Paradise to demonstrate the value of applying lake sediments to farmland to restore soil fertility while extending the life span of the lake. The high concentration of nitrogen and phosphorus in the sediment actually reduced the demand for artificial fertilizers.

The Lake Paradise study has inspired other communities to use lake sediments as a soil supplement. One such community is Springfield, which is now enriching farmland surrounding Lake Springfield with sediments from the lake.

Sedimentation in Lake Peoria, on the Illinois River in west-central Illinois, reflects the degradation of that river's water quality. Citizens in the area have joined to study the problems and develop solutions to reduce the sedimentation in the river and in adjoining lakes and wetlands. The Water Resources Center is cosponsoring research and conferences on many of the water issues that affect Lake Peoria and many similar lakes and streams throughout Illinois.

Recently, the center has supported research examining the impacts of agricultural practices on groundwater, and on the runoff of surface water or subsurface flow through soils and tiles into the streams. These waters supply cities with water for public use and require costly treatment to remove nitrates and trace organic chemicals from pesticides. Reports published by the American Water Works Association indicate that home water rates are likely to increase from 50 percent to 100 percent to meet new, more stringent drinking water standards established by the U.S. Environmental Protection Agency for the contaminants.

Water resources research will become increasingly important. As we find solutions to many of our water problems, new ones will arise. And agriculture's impact on our water resources will undoubtedly continue to warrant the attention of the Water Resources Center, which will persist in helping Illinois soundly manage its water for the welfare of its citizenry.

Glenn E. Stout, director of the Water Resources Center, and Holly B. Korab, writer/editor for the center ■

PHOTO COURTESY ILLINOIS-INDIANA SEA GRANT PROGRAM

Chicago lies at the south end of Lake Michigan, perfectly situated as a commercial center and transportation hub.

Sea Grant Explores Water Quality in Lake Michigan

The waters of southern Lake Michigan offer something for everyone. Excellent swimming, fishing, and boating opportunities attract not only the area's 8 million residents but also thousands of visitors each year.

In addition to being a recreational attraction, Lake Michigan also provides many economic opportunities for local businesses — such as charter fishing. One of the fastest growing industries in the Great Lakes region, charter fishing brings in $100 million per year. Of course, Lake Michigan also provides municipal water for many cities in Illinois and in northwest Indiana.

During the past century, human and industrial pressures have taken a toll on the lake. The high population density near the limited shoreline creates a significant impact, as do the industrial waste and surface runoff along the lake.

All residents of Illinois and Indiana have a stake in the "health" of Lake Michigan. Federal income taxes are used to clean up seriously polluted areas identified as U.S. EPA Superfund sites. One of these is Waukegan Harbor, Illinois — where the presence of PCBs, potentially carcinogenic contaminants, restricts use of the harbor for fishing and swimming. Commercial shipping has also had limited access to the harbor due to restrictions on disposal of contaminated sediment dredged from the harbor.

The Illinois-Indiana Sea Grant Program is part of a national network of universities meeting changing environmental and economic needs of people in coastal, ocean, and Great Lakes regions. The research component of the program funds projects addressing water-quality concerns to ensure the productivity of Lake Michigan's fishery and to provide cleaner water for numerous recreational activities.

Three recent projects funded by Sea Grant are examining the degradation of water quality in southern Lake Michigan. All three projects shared the goal of reducing impacts from either industrial or agricultural pollutants.

The first study focused on protecting streams from agricultural pollutants and illustrated how proper management of farms could improve water quality and habitat for fisheries and streams. University of Illinois researchers Robert Larson, Edwin Herricks, and John Braden developed a pollution risk-management framework for identifying priority areas to control damage to fisheries habitat in Great Lakes tributaries caused by agricultural sediment and sediment-associated pollutants.

Different policy options — based on erosion, sediment load, and habitat suitability — were analyzed for their effects on abatement costs and the likelihood of achieving suitable habitat quality. The findings suggest that small and inexpensive changes in farming practices, if strategically located and timed, can significantly improve habitat quality.

One implication of this study, said Herricks, is that more ambitious fish protection goals should be matched with programs geared to more factors affecting stream quality — in particular, agricultural pesticides. The researchers also suggest that no-till farming can hurt fish because of pesticide concentrations in runoff.

Human and industrial pressures have taken their toll on the lake.

A second study focused on the effects of sunlight on the toxicity levels of hydrocarbon pollutants. These pollutants can occur from city street runoff, refinery discharges, and boat engine leakage. UI researcher Richard Davenport, along with Anne Spacie of Purdue University, examined a new class of environmental damage that had been previously overlooked.

The two researchers discovered that the environmental impact of petroleum pollution is far greater than previous estimates, which did not account for the role of sunlight in raising toxicity levels.

Sunlight reaches the toxic sediment when activities such as dredging and shoreline modifications stir up the contaminated lake bottom materials. Boat traffic and severe weather can also increase light-induced toxic effects on the aquatic environment.

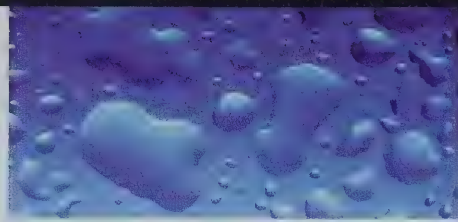
"Toxicity can increase 1,000-fold when experiencing light," Davenport said. Such toxicity has been found instrumental in causing spinal cord defects in developing fish and frogs, he added. Other research also has demonstrated that these toxicants are passed through the fish food chain.

A third Sea Grant–funded study is trying to determine why the environment is not cleansing itself of polycyclic aromatic hydrocarbons (PAHs). These pervasive materials were released into the water as far back as 100 years ago. The study is focusing on the effects of adding microorganisms to accelerate the breakdown of PAHs, which have been shown to cause cancer in humans, according to Ron Turco, soil microbiologist at Purdue University. The breakdown of these PAHs is limited, according to Turco, because they adhere both on and in the sediments of the Grand Calumet River. Turco and Allan Konopka, a biologist at Purdue, noted that bacteria cannot readily consume these compounds because they dislodge slowly over time.

Microorganisms, referred to as "bugs," are being added to the water environment to gain a clearer picture of what limits the degradation of PAHs. "The bugs isolated by the research community over the past two decades have served as a backbone for the bioremediation industry," said Turco. This industry uses living organisms to break down toxic compounds for improved water quality.

The ultimate goal of these and other studies is the elimination of toxics from the entire lake system. Attaining this goal requires a close look at the toxins in the lake's fish, wildlife, and human populations. Measuring the levels and effects of these contaminants is critical to understanding how they can best be reduced.

Sea Grant research on water quality will continue to provide building blocks of information toward the goal of cleaner water. Results of these studies will help reveal what toxic substances exist and how they are changing over time.
— Robin G. Goettel, communications coordinator, Illinois-Indiana Sea Grant Program



Students Get Their Feet Wet

Robert Williams and Cindy Bidlack

On October 15, 1992, a small army of high school students from six midwestern states spread out across the Mississippi River watershed for a day of observation and data collection. This was the fall test date for the Illinois Rivers Project, an innovative research program created by Robert Williams, a professor of science education at Southern Illinois University at Edwardsville (SIUE).

The project's multidimensional approach integrates scientific, technological, and societal issues into an experience that teaches students the importance of their local rivers and streams. Students must draw on their knowledge of not only science but also social studies and language arts in their detailed study of local waters.

The Illinois Rivers Project began modestly in January 1990, when eight high schools helped monitor the Illinois and Mississippi Rivers near Edwardsville, Illinois. Bolstered by grants from the Illinois State Board of Education, the U.S. Fish and Wildlife Service, and the National Science Foundation, the project has expanded to include 180 high schools in Illinois, Wisconsin, Iowa, Minnesota, Missouri, and Indiana, covering a major portion of the Mississippi

Kwa Mister helps anchor Leanne Mispagel as she leans over the Mississippi River to collect a water sample as part of the Illinois Rivers Project. The students attend high school in Cahokia, Illinois, near St. Louis.

River watershed. Support also comes from the University of Illinois Water Resources Center and Illinois-Indiana Sea Grant Program.

A Precious Resource

The Mississippi watershed contains some of the finest agricultural land in the nation, and one of the area's most precious resources is its system of waterways. Changes in the quality of these waters reflect changes in the groundwater and precipitation that feed them.

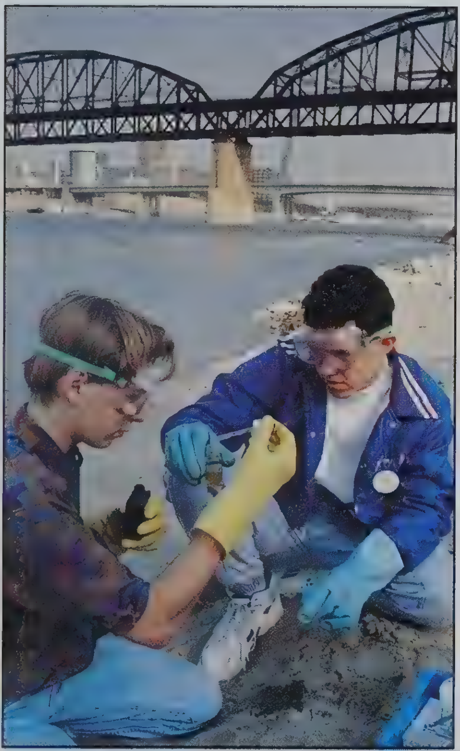
Students involved in the Illinois Rivers Project perform nine water-quality tests at selected sites along their local river or stream. They test for dissolved oxygen, biochemical oxygen demand, pH, temperature, total solids, turbidity, total phosphorus, nitrates, and fecal coliform. The oxygen tests measure one of the most critical indicators of the waters' ability to support aquatic life. The pH and temperature tests reveal much about the diversity of life forms found along and in the stream.

Perhaps of greatest agricultural interest are the tests of turbidity and total solids. Both of these tests provide a direct measure of the erosion of topsoil from the watershed drained by the river or stream. The tests for total phosphorus and nitrates measure the level of these critical nutrients in the water. Although in the past agriculture has taken much of the blame for increased levels of these chemicals, much of the problem derives from inappropriate use of fertilizers on lawns and golf courses as well as industrial wastes.

The final test, the fecal coliform test, measures the presence of bacteria in the water. Both humans and animals are sensitive to changes in these levels.

To measure overall water quality, students convert the result of each test into a "quality value" and then add the nine values. The sum is expressed as an "overall water-quality index." Specific index values can then be used to establish safe human uses for the water (see illustration).

These tests, together with the students' survey of the bottom-dwelling organisms



Science students Ryan Trepka (left) and Jim Bryant, from Cahokia High School, measure the amount of dissolved oxygen in a water sample taken from the Mississippi. Trepka is planning a career in accounting or chemistry. Bryant hopes to become an environmental engineer.

Water Quality Index (WQI) - Cahokia

Date 10-29-92 **Time** 0930

Test Location Mile Marker 179, Mississippi River

Weather Conditions Windy - 34°F

	Test Results (Column A)	Q-Value (Column B)	Weighting Factor (Column C)	TOTAL (Column D)
1. Dissolved Oxygen	125 %Sat	87	0.17	14.8
2. Fecal Coliform	210 colonies /100ml	36	0.16	11.4
3. pH	8 units	85	0.11	9.4
4. B.O.D.	3.5 mg/1	72	0.11	7.9
5. Temperature	0 Δ°C	93	0.10	9.3
6. Total Phosphorus	1.1 mg/1	38	0.10	3.8
7. Nitrates	4.0 mg/1	80	0.10	8.0
8. Turbidity	0.5 /feet	12	0.08	1.0
9. Total Solids	310 mg/1	58	0.07	4.1

Overall Water Quality Index 69.7

Instructions:

1. Record the river data in Column A
2. Record the Q value (from the charts) in Column B
3. Multiply the values in Column B by the weighting factor in Column C and record the results in Column D
4. Add the Values in Column D to get the Overall Water Quality

Atrazine: What Is Its Link to Rural Water Quality?

Atrazine is the most commonly used pesticide in Illinois. It is also one of the most frequently detected pesticides in surface water and groundwater.

Because of its prevalence, atrazine has been the focus of several recent research projects to determine how it is affecting the state's water supplies.

One of the research projects was the "Pilot Study of Agricultural Chemicals in Rural Private Wells in Illinois." Completed in March 1992, the study was conducted jointly by the State Water Survey, State Geological Survey, and Illinois Department of Agriculture.

Researchers involved in the study selected sampling sites based on the assumption that wells drawing water from deep aquifers are less vulnerable to contamination from field chemicals than wells nearer the surface. The goal of the pilot study was to evaluate Illinois groundwater on a small scale to determine: (1) the possible extent and magnitude of contamination from agricultural chemicals; and (2) the need for a large-scale statewide survey.

Researchers concluded that the depth of an uppermost aquifer was indeed useful for predicting the occurrence of agricultural chemicals and that a statistically valid statewide survey was needed.

Another recent, ongoing study focuses on agrichemical contamination of shallow, large-diameter wells. Funded by the U.S. Department of Agriculture through the Illinois Groundwater Consortium, this research project employs observational rather than statistical methods to discover whether certain situations or factors tend to produce higher instances of contamination.

Sampling sites were chosen in rural areas where the land use is corn and soybean production and the water supplies are typically shallow, large-diameter wells. Large-diameter wells are found throughout rural areas of Illinois where shallow groundwater supplies are limited. There has been minimal research into the vulnerability of these types of wells. The goal of this project is to develop an understanding of the magnitude and extent of any contamination in these distinctive types of wells and to determine what factors contribute to well vulnerability. — *Steven D. Wilson, assistant hydrologist, State Water Survey*

found at the test site, are then forwarded to the Illinois Rivers Project office at SIUE via a computerized telecommunications network. All data are fed into a database accessible by the participating schools as well as environmental groups. At the end of the school year, the U.S. Fish and Wildlife Service receives the data for inclusion in its Geographic Information System database, for use by researchers across the nation. In addition to the GIS, the Illinois Environmental Protection Agency uses the data as a scanning device to identify potential water problems that might otherwise go undetected.

Although the Illinois Rivers Project requires participant schools to sample their sites only four times during the school year, most schools have adopted biweekly or monthly sampling schedules. The schools thus provide an early warning system when water quality changes occur, enhancing the water-monitoring capabilities of government agencies with limited personnel and monetary resources.

More Than a Science Project

The Illinois Rivers Project covers more than just science. The students also study the history of the river's effect on their local community through interviews with people who have lived or worked near the river. Their research is rounded out with a look at the river's importance to local development and the legal codes applicable to land usage and water quality in the area.

In their language arts classes, students learn how to document their scientific results and historical research; how to write letters to local newspapers, politicians, and community organizations advocating water-quality control measures; and how to make public presentations about the project. They also have an opportunity to express their feelings about their local rivers or streams through creative writing and visual arts.

Through the Illinois Rivers Project, students gain a better understanding of the intricate relationship between land usage and water quality. They discuss the effects of taxing agricultural land based on its productive rather than its market value. They see how converting agricultural land to urban uses affects water runoff and may contribute to soil erosion and the chemical pollution of watersheds. After interviewing local farmers, business owners, and residents, the students can better appreciate the symbiotic relationship that exists between these apparently conflicting public interests.

The Illinois Rivers Project was designed to educate students on the problems involved in making important value judgements on land usage. By focusing on the local rivers and streams, students can see how their decisions can affect future generations as well as their own.

Illinois Rivers Project staff: Robert Williams, director, and Cindy Bidlack, coordinator

Biological Indicators of Water Quality

Throughout history, humans have used plants and animals as indicators of the safety or quality of the environment. Primitive peoples undoubtedly understood that dead animals at a water source warned against the use of that water.

Today's indicators of water quality certainly are more sophisticated than in the past, yet the basic principles of biological monitoring have not changed. Scientists now use controlled experiments in the laboratory, called toxicity tests, or careful observation of the numbers and kinds of plants and animals in natural settings, called field assessments, to indicate water quality or health.

In toxicity tests, plants or animals are exposed to several concentrations of a pollutant to determine how much of the pollutant is needed to produce a response in a given time. Results from these tests are used to set water-quality standards. They also provide a basis for a pollutant-specific assessment of water quality. Because different plants and animals may have different sensitivities to pollutants, test batteries may employ several species and several measures (ranging from acute effects — often death — to chronic effects that may include subtle physiological, reproductive, or behavioral responses in test populations).

Although toxicity tests provide valuable information on pollutant effects, environmental impact predictions are sometimes inaccurate because the laboratory-based toxicity testing cannot account for all of the environmental factors that may alter the pollutant's effect on the receiving waters, which change with weather and season.

To determine the actual effect of a pollutant in the environment, observations of organisms in their natural setting are made. These field assessments typically determine the number and kinds of organisms in areas with and without a pollutant.

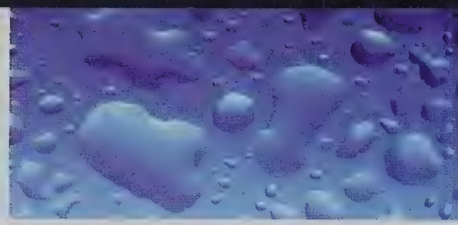
By observing many streams and lakes, it is possible to assess relative health using indices. The indices are usually based on a knowledge of a species' sensitivity to pollution and the possible interactions among species in the ecosystem. An index developed in Illinois, known as the Index of Biotic Integrity (IBI), is used to assess stream condition based on fish species present. Other indices assess water quality using the relative numbers of aquatic insects that are tolerant or intolerant of pollution. — *Edwin E. Herricks, professor of environmental biology, Department of Civil Engineering*

Factors Affecting Biotic Integrity

Ecological impact of human-induced alterations

Ecological impact of human-induced alterations	1. Energy source →	Change in the way plants and animals use sun's energy
	2. Water quality →	Presence of toxic substances or other chemicals that affect aquatic life
	3. Habitat quality →	Erosion, siltation, and degradation of habitat
	4. Flow regime →	Change in flow volume or frequency
	5. Biotic interactions →	Change in relationships among organisms

Source: Adapted from Assessing Biological Integrity in Running Waters, by James Karr et al., Illinois Natural History Survey, 1986, SP5, page 3.



Big Opportunities for the Little Vermilion

J. Kent Mitchell and Allan S. Felsot

The village of Georgetown draws its water from a reservoir created by the construction of a dam across the Little Vermilion River. In recent years, this small community in east-central Illinois has seen cropland erosion cause heavy sedimentation in its reservoir, also known as Georgetown Lake.

The sedimentation is slowly filling up the reservoir, which has been reduced to just 49 percent of its original capacity. In addition, nitrate levels in the Little Vermilion River near Georgetown often exceed water-quality standards. Scientists assume that pesticides are also present in the water supply.

An ambitious project in the Little Vermilion River watershed is focusing on reducing the levels of nitrates, pesticides, and sedimentation in Georgetown Lake from agricultural sources.

Improving Land Management

The project sponsors — the Cooperative Extension Service, the Soil Conservation Service, and the Agricultural Stabilization and Conservation Service — are encouraging farmers to use "best management practices" (BMP) throughout the watershed. These practices should help to improve the quality of water in the lake and maintain good water quality in aquifers that serve private wells.

Researchers from the Department of Agricultural Engineering and the Office of Agricultural Entomology at the University of Illinois are in charge of monitoring selected management practices. Their goal is to determine to what extent BMP can eliminate, reduce, or retard movement of agrichemicals to groundwater and streams. The results of these studies will be used to demonstrate the effects of these practices throughout the Little Vermilion River watershed.

Researchers Go Underground

Soil Conservation Service field personnel have helped select six small subsurface drainage systems for the study. The watersheds have a systematic tile-drainage system, and the exact location and amount of tile are known. Four tile-drainage monitoring sites were installed in 1991. At one location where soils are predominantly Sabina silt loam and Xenia silt loam, a 20-acre subsurface drainage system is under no-till, row-crop management. A second subsurface system drains from a 20-acre field in permanent grass.

The soils are predominantly Flannagan silt loam and Drummer silty clay loam at

Lowell Gentry

Walter Scott

the second location, which contains two subsurface drainage systems of approximately 4 and 7 acres. Both are in a reduced-till, row-crop management system. Crops are alternated each year with one field in corn and the other in soybeans.

Two other tile drainage sites were selected during the fall and winter of 1991–92, and monitoring equipment was installed during the summer of 1992. The drainage sites are on predominantly Flannagan silt loam and Drummer silty clay loam. One site is a 40-acre system under corn-soybean conventional tillage management. A 7.8-acre system under high-nitrogen, conventional-till seed corn management was selected for the second site.

Surface runoff monitoring has not begun at the subsurface sites. Those monitoring stations will be installed in 1993. When surface runoff is occurring, a proportional sampler will be used to collect water samples. These samples will be analyzed for nitrate and pesticide concentrations in the water and sediment. The rate and volume of surface runoff will be monitored continuously.

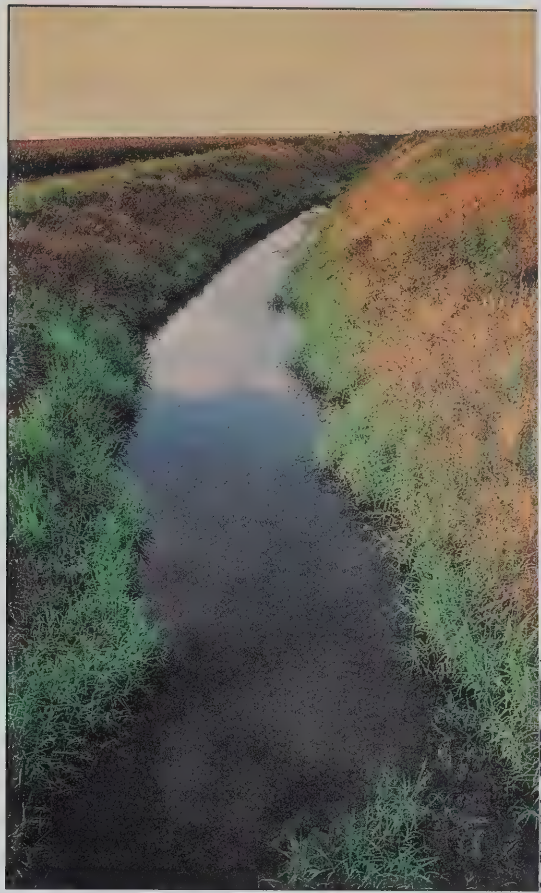
Keeping an Eye on Agrichemicals

All agrichemical applications to the monitored fields will be recorded. Soil sampling will provide data for concentration of agrichemicals already in the field soil. Measured volumes of subsurface flow and surface runoff with measured concentrations of nitrates and pesticides will provide information to determine the total (or per-unit land area) agrichemical loss in the flows. This study will allow the quantification of nutrients and pesticides in groundwater and surface water.

Some landowners and operators have been reluctant to cooperate with monitoring projects because they fear that data on specific land will be made available to regulatory agencies. Therefore, cooperators have been assured that locations of the data collection sites will be kept confidential. Reports will include tillage and cropping practices on a site; soils included in the watershed draining to a site; runoff or tile flow amounts; and nutrient and pesticide amounts.

Using Filter Strips

In addition, the researchers will evaluate the effectiveness of vegetative filter strips in removing sediment, nutrients, and pesticides from runoff. The filter strip study will include six plots approximately 6 meters wide and 18 meters long on a sloping, conventionally cropped field. A grass- or legume-vegetated strip at least 6 meters wide will be located at the lower slope of the field. Three of the plots will end at the boundary between the cropped field and filter strip. These plots will provide data about runoff and chemicals entering the filter strips. The other three plots will extend through the filter strips and provide data on how vegetated filter strips affect ground- and surface-water quality.



Vegetative filter strips help remove sediment, nutrients, and pesticides from runoff.

At the time the plots are established, soil samples will be taken to determine critical soil characteristics and current concentrations of nutrients and pesticides. Surface runoff will be monitored continuously. Subsurface flow will be estimated in each plot using measured hydraulic conductivity, and open-tube sampling piezometers (small wells) will be used to establish flow gradients in the soil. A pump will collect runoff samples; the samples will then be analyzed for sediment concentration, nitrate concentration, and concentration of phosphorus and pesticides in water and sediment. Subsurface water samples will be collected from the small wells.

Lowell Gentry

The type of wetland construction illustrated by the photos above and at left is planned for the Little Vermilion watershed. Pictured at far left is an aerial view of the Embarras River in southern Champaign County. Middle photo shows detail of a new wetland site seen in far left photo (new site is located along the river, to the right of the farmstead). Above, heavy rainfall causes dug-out areas to fill up, creating a wetland. Photographs are from an ongoing research project conducted by UI scientists David Kovacic, Kenneth Konyha, Mark David, and Lewis Osborne.

Building Wetlands

The researchers also plan to monitor two small wetland sites to determine the effect of wetlands on water quality. These sites will be at the outlet of a small tile-drained watershed that is intensively cropped. Soils will be sampled to determine critical soil characteristics and concentrations of nutrients and pesticides. The intensity of soil sampling will depend on the size of the wetland and the base soils present. Similar soil sampling will be done annually to measure changes in the wetland soil.

As with surface runoff, combined surface and tile-drainage flow entering the wetland will be measured continuously. Surface flow leaving the wetland will be measured similarly. A pump sampler will be used periodically during base flow periods to sample surface flow and more often when runoff is occurring. These samples will also be analyzed.

To learn how agrichemicals move from wetlands to groundwater, transects of open-tube sampling piezometers will be placed in and outside of each wetland to determine subsurface flow gradients. Subsurface water samples will also be collected periodically for nitrate analysis. This monitoring program will allow quantification of water flow and chemical flux into and out of each wetland, and the amount of reduction of agrichemicals in groundwater and surface waters. With these data, a great deal will be learned about how wetlands help reduce the amount of agrichemicals in water supplies.

After all the data from the various components of the project have been collected, the researchers will then be able to create models of alternative watershed practices. The goal is to be able to apply these models to other appropriate land areas and to be able to predict changes in water quality in the Little Vermilion River and Georgetown Lake.

J. Kent Mitchell, Department of Agricultural Engineering, and Allan S. Felsot, Center for Economic Entomology ■

Rethinking Wetlands

Swamps, marshes, fens, and bogs were once considered worthless lands. So worthless that more than 85 percent of Illinois's original 8 million acres of wetlands have been lost — converted by drainage into some of the most productive agricultural lands in the country.

But during the past 20 years, the value of wetlands has been rediscovered. Wetlands have been found to be essential to the survival of thousands of plants and animals, including many popular game birds and half of the animals on the nation's endangered species list. As a result, President Bush declared that there should be "no net loss of wetlands," and the development of wetlands around the country is now regulated through section 404 of the Clean Water Act (1975) and the "swampbuster" provisions of the Food Security Act (1990).

But wetlands do more than protect our nation's biodiversity.

Wetlands can also improve water quality by providing sediment control, filtration and biodegradation of synthetic chemicals (including pesticides), and possibly the fixation of toxic metals. Wetlands also actively remove fertilizers from agricultural runoff during the growing season and can convert nitrogen from polluting forms such as nitrate, ammonia, and nitrites into harmless elemental nitrogen gas. Much remains unknown, however, about the mechanisms controlling these water-quality improvement processes.

Scientists at the University of Illinois are involved in three projects to assess the water-quality benefits of wetlands. One study, part of the Little Vermilion River Project, examines the effectiveness of constructed wetlands and buffer strips in removing pesticides, sediment, and nitrates from agricultural runoff waters. The study is sponsored by the Illinois Groundwater Consortium.

A second project, funded by a National Research Initiative grant, involves scientists from the University of Illinois, the Illinois Natural History Survey, and the Wetlands Research Laboratory at Louisiana State University. Their three-year study focuses on nitrate transformations, uptake, and removal by constructed wetlands receiving agricultural runoff water.

A third project, sponsored by the Illinois Groundwater Consortium, examines nitrate transformations, uptake, and removal in a constructed detention buffer strip receiving agricultural runoff water.

All three projects involve detailed analysis of the hydrology and chemical transport within small (1- to 2-acre) wetlands. All of the wetlands under examination are being reclaimed from poorly drained, low-value agricultural land. Studying the behavior of these individual wetlands will help determine how natural and constructed wetlands function in Illinois. This research should also clarify the processes required to create a functioning wetland.

Restoring a small fraction of our lost wetlands not only will restore valuable wildlife habitats but also may provide a cost-effective method for improving our nation's water quality. — *Ken Konyha, assistant professor, Department of Agricultural Engineering*

Improving Urban Water: Turf Put to Test

It is no surprise that discussions about Illinois agriculture and its effect on water quality deal mainly with crop production practices. After all, farmland acreage in the state far exceeds the amount of lawns, parks, and other turf areas. But, even though they take up a relatively small amount of space, urban areas cannot be ignored in terms of their influence on water quality. In fact, the urban environment has a tremendous potential for improving water quality.

Research conducted in Illinois and many other states has shown that turfgrass stands are excellent sites to apply wastewater discharged from sewage treatment plants for purification and potential groundwater recharge. Turfgrasses are perennial plants with a dense, fibrous root system that helps filter out the nutrients in the wastewater and use them for growth. The availability of wastewater reduces the need for application of potable water, thus helping conserve this important resource.

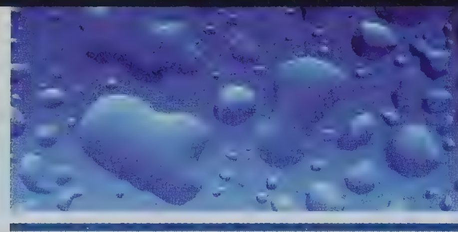
Cantigny Golf Course

At the Cantigny Golf Course outside Chicago, treated wastewater is used to irrigate the turfgrass. The turf's dense, fibrous root system filters out nutrients from the wastewater and uses them for growth.

Limitations on the use of sewage wastewater, or effluent, deal with the economics of its distribution system and the presence of salt. So far, only golf courses adjacent to sewage treatment plants have access to this type of water. It is usually cheaper to rely on wells or potable water for irrigation than to build a pipeline from a distant treatment plant to the golf course. The salt content of the effluent may limit its use as a source of irrigation, especially in communities where numerous home water softeners discharge into the sanitary sewers. At the Cantigny Golf Course in Wheaton, a suburb west of Chicago, this problem is solved by mixing effluent with water from rainfed ponds to dilute the concentration of salt. Natural rainfall helps wash the salt from the soil, as is the case here in Illinois. In more arid climates, however, salt buildup from wastewater use is more of a problem.

Although the urban environment can be used to improve water quality, it also has the potential to damage it. Pesticides and fertilizers are used to maintain high-quality turfgrass stands, and where there is an opportunity to misapply a pesticide or fertilizer, water quality can be diminished. Fortunately, the same characteristics that make a turfgrass stand such an excellent place to apply effluent also provide a safety factor ensuring that properly applied pesticides and fertilizers will not hurt the water. In addition to having dense root systems, turfgrass stands have a layer of organic matter called thatch between the soil surface and the grass blades, or shoot system. Thatch helps intercept pesticides, much like a layer of crop residue on a no-till farm field, and holds them until they are degraded by microorganisms in the soil.

Proper lawn fertilization helps maintain good turf density which, in turn, prevents weed encroachment and reduces the need for herbicides. Many of us have seen yellow-green stripes on a fertilized lawn where the homeowner did not overlap the wheels of the spreader. The stripes demonstrate the fact that nitrogen does not move laterally in a turfgrass stand. Research has shown that where turfgrass is present, nitrogen from normal fertilizer applications is rapidly intercepted and used by the plants so that there is essentially no movement — vertical or horizontal — through the turf profile. Simply preventing fertilizer from being thrown onto driveways or sidewalks where it may be washed into the storm sewers will help prevent a negative impact on the environment. — *David J. Wehner, associate professor of turf science, Department of Horticulture*



Consortium Focuses on Agrichemicals in Groundwater

Victoria J. Molfese

The Illinois Groundwater Consortium grew out of a $500,000 federal appropriation to Southern Illinois University at Carbondale to focus on the short- and long-term effects of agricultural chemical contamination on the environment, the groundwater, and, ultimately, human health and welfare. SIUC joined forces with the State Geological Survey, State Water Survey, University of Illinois Cooperative Extension Service, and the UI Agricultural Experiment Station to provide a scientifically valid basis upon which meaningful agricultural chemical management and regulatory decisions could be based.

Priorities for Research

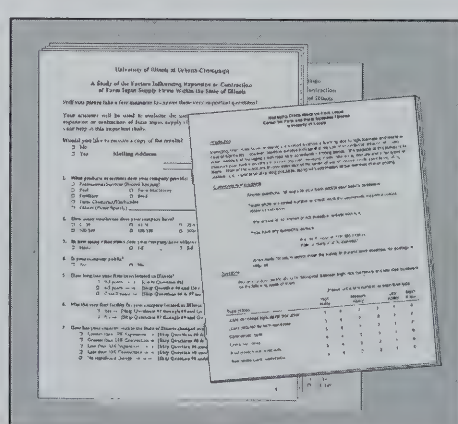
The goal of the consortium research was not to diminish the nation's agricultural productivity nor its cost effectiveness. The real purpose was to show that the deterioration of the environment can result in unpredictable costs — as has been seen for industries employing fossil fuels in their operations. (For example, coal-burning plants have had the hidden cost of adding scrubbers to reduce sulfur emissions in compliance with the federal Clean Air Act.) Taken into account were the concerns of not only the agricultural and agrichemical industries but also the agencies charged with protecting the environment.

Major research priorities of the nationally regarded program included generating information on the occurrence, transport, and fate of agricultural chemicals in representative hydrogeological settings in Illinois, and the effects of regulatory and incentive policies and strategies. Now in its third year, the consortium is continuing to help acquire and process information gained from investigations conducted by consortium scientists. Sixteen projects are currently under way, and eight new projects will begin this year.

From the beginning, the consortium has focused on six broad-based areas, described below, needing more research activity but for which little government funding is available.

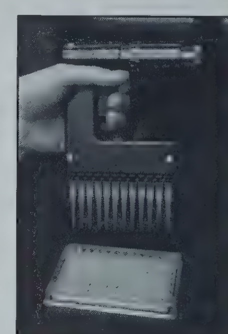
Determining Which Research Techniques to Use

Surveying both current and past practices of fertilizer and pesticide usage in Illinois has been useful in estimating the potential for contamination in various parts of the state. The surveying also permits a more informed selection of methodologies and analyses for sampling programs. Information obtained through surveys and studies of farm businesses will provide a foundation from which to expand the application of new methodologies to minimize any harmful influence of agrichemicals on groundwater.



Assessing Groundwater Quality

Broad-based sampling programs are being developed, some of which represent expansions of current pilot studies at the State Geological Survey and State Water Survey to determine, for a broader region, the quality of groundwater in rural water supplies. One important aspect of the expanded programs is the assessment of agricultural chemical contamination of shallow bored and dug wells. Seasonal sampling is being carried out to determine whether certain agrichemicals are reaching groundwater supplies. Soil sampling procedures will be coordinated so that soil and groundwater samples can be obtained from adjacent locations and across different soil types.



Computer models of agrichemical, soil, biological, and groundwater interactions will be used to predict the fate of various constituents and to predict regional groundwater flow. Models will also help predict contaminant transport and adsorption (condensation) in various earth materials and in streams. Additional input data are needed for these models.

Improved analytical methods for the isolation, detection, identification, and measurement of pesticides in the soil and groundwater are also being developed. For example, the Pesticide Pilot Study is evaluating the various components of the experimental design of a statewide survey of pesticides in groundwater.

The primary goal of the pilot study is to ensure that the results of the statewide survey will be valid. To that end, two fundamental questions are being asked. First, are the wells to be sampled representative of all rural, private wells in Illinois? Second, are the results of the chemical analyses accurate?

Techniques to measure basic material properties influencing how contaminants are transported by water are being developed in this and other projects. Teams are investigating the relationships between the distribution and basic characteristics of the surficial geologic materials (including fracture density and spacing, texture, and mineralogy) to the hydrologic properties of these materials. In addition, comparisons are being made across studies to determine the accuracy of measuring atrazine contamination across different methodologies and different laboratories

How Agricultural Practices Affect Groundwater

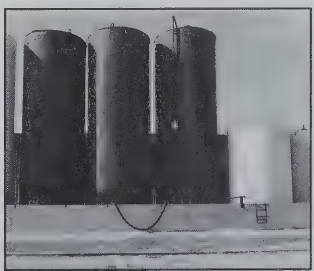
This component involves the study (through computer modeling and field studies) of how variations in the quantity, form, timing, and frequency of pesticide and fertilizer application affect changes in chemical structure and chemical transport. These studies also consider the effects of topography and precipitation on pesticide and fertilizer transport, and the effects of tilling on herbicide movement. A final part of this component focuses on how fertigation (applying fertilizers through irrigation systems) affects groundwater quality.

Do Regulations and Incentives Work?

The effects of regulations and incentives on both agricultural and nonagricultural communities are being studied. Any regulatory or incentive activity relating to agricultural chemicals will affect both the operation and the profitability of agribusinesses. It will also influence the price of food products.

Research efforts in this area include evaluations of existing regulatory and incentive models from other industries to determine their applicability to agriculture, analysis of the impact of additional regulations on groundwater resources and the regional rural economy, and the feasibility of nonregulatory approaches to groundwater protection. Ideally, these studies will be conducted in more than one county in Illinois and will provide useful data for testing various groundwater models.

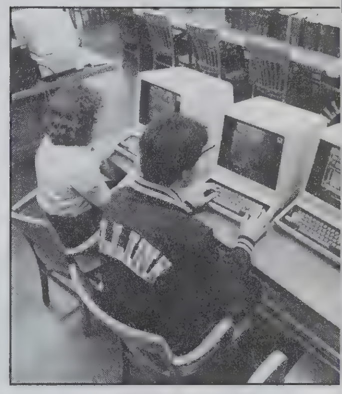
How to Protect Water *and* Business



The goal is to develop overall methodologies and strategies that lead to groundwater protection while minimizing adverse effects on farms, agribusinesses, and food prices. Through educational programs, these strategies will be shared with fertilizer and pesticide users and the general public. Currently a state legislative committee is developing a strategy in response to the U.S. Environmental Protection Agency. A new brochure detailing ways to protect groundwater has just been developed in one project funded through the Consortium.

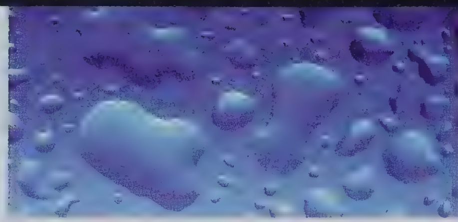
Getting the Word Out

The Illinois Groundwater Consortium is working to further incorporate its research findings into educational materials and Extension activities. The consortium is involving undergraduate and graduate students in groundwater geology, hydrology, environmental chemistry, agricultural sciences, and economics. These students are involved at various levels in the development and conceptualization of the research plan and purpose, and in a variety of tasks, including data gathering, data management, and data analysis. Student involvement is one of the most cost-effective methods of information transfer. This program offers students a unique opportunity to get a head start on their careers. In addition, brochures, proceedings, and other materials are being prepared to help provide information to researchers and general audiences on groundwater contamination and protection strategies.



The outcome of these research efforts will be a scientifically valid, statewide database of information that will help both the state and the nation effectively manage and preserve our precious groundwater resources.

Victoria J. Molfese, director, Illinois Groundwater Consortium ■



The Making of the River Sands Project

Tina M. Prow

The Imperial Valley of the Midwest cannot be found on a map. Carved out by farmers, it is defined by pumpkins, peas, cucumbers, sweet corn, green beans, popcorn, and seed crops grown on more than 100,000 acres east of the Illinois River.

The vegetables thrive in the sandy soils of a prehistoric river bed that runs through Mason and Tazewell counties. Since the late 1950s, area farmers have tapped into the Sankoty aquifer for a supply of on-demand water to keep the crops healthy.

A Delicate Situation

Although the aquifer and sandy soils make the Imperial Valley of the Midwest possible, they are a precarious combination for agricultural production involving chemicals. The aquifer is shallow, less than 5 feet from the soil surface in some areas. The sandy soils above it have little clay or organic matter to hold agricultural chemicals at the surface.

Yet each year, farmers plant more acres to high-value specialty crops, which

Pumpkins are just one of the high-value specialty crops that are a mainstay of farming in Mason and Tazewell counties, site of the River Sands Water Quality Project.

often require high amounts of chemical inputs. In Mason County, the number of irrigated systems installed to ensure water for the crops increased from 11 to more than 800 over the past two decades. With each new system and each additional acre planted to a specialty crop, concern about the effects that intensive, irrigated agriculture might have on the water supply have become more pressing.

"Water is our most important natural resource," said Edward Whitaker, a retired farmer. The family farm south of Forest City, acquired in 1920, is run now by Whitaker's nephews.

"Farm families drink water from the aquifer and depend on the water for specialty crops. We want to farm so that water quality is preserved or improved. Our concern is for production, but it's also personal," he said.

Launching a Grass-Roots Effort

That concern spurred citizens to form the Water Issues Resource Planning Committee in 1989. Whitaker, who was Mason County Farm Bureau president then, was on the committee, along with representatives from the Mason County Board, government agencies, farming associations, and the University of Illinois Cooperative Extension Service and Illinois Agricultural Experiment Station. The group's early goal was to have part of Mason County identified as a Hydrologic Unit Area. With an HUA designation would come funds for research and education from a new federal program known as the President's Water Quality Initiative, administered by the U.S. Department of Agriculture.

Once the course of action was set, the committee began to gather facts for a proposal that would show the USDA how groundwater could be improved in Mason County. The plan of work, a year in the making, gained a broad base of support, including support from members of Congress, state representatives, and state senators.

In January 1990, USDA approved the initiative: the Illinois River Sands Water Quality Project became one of 74 HUAs funded across the country and one of only a half-dozen HUAs to include groundwater. For the next five years, the UI Cooperative Extension Service, Soil Conservation Service, and Agricultural Stabilization and Conservation Service would cooperate to develop programs and strategies aimed at reducing the amount of agricultural nutrients and pesticides reaching the aquifer.

"The goals are, broadly, to protect groundwater quality and reduce ag chemical contamination of the aquifer," said George Czapar, an Extension integrated pest management educator and project contact.

Although the River Sands Project area covers only 390 square miles, many of the practices being developed to protect groundwater could be adopted by other farmers. In fact, Czapar said he incorporates information coming out of the project into his day-to-day efforts to help growers in western Illinois improve pest management and protect groundwater.

"With the sandy soils, the shallow aquifer, and the intensive use of agricultural chemicals, Mason County really defines groundwater vulnerability," he said. "Everyone has to make an effort to try to do the right thing."

Finding the Source of Problems

Work to find out what the "right thing" is in Mason County began with a survey to assess wells and potential problems. One finding was that 70 percent of the surveyed wells were shallow, "sandpoint" wells. These wells, less than 40 feet deep, are more prone to contamination than deeper wells. The proximity of septic systems and abandoned or nonoperating wells surfaced as other potential sources of contamination.

The project team also looked at irrigation systems and moved quickly to solve a potential wellhead problem. Many farmers were applying nitrogen through irrigation systems, a sound practice for minimizing leaching. Although new systems had safeguards built in to prevent accidental contamination of wells, many of the older irrigation systems did not. Through the project, ASCS and SCS provided cost-share money to cover 75 percent of the expense of installing safeguards on the older systems. More than 300 old systems now have backflow valves to prevent nitrogen solution from flowing down a well if power or equipment fails.

'There's a genuine interest in seeing the minimum level of herbicide and insecticide used.'

"The thought was that if even one case of backflow down a well could be prevented, then that was money very well spent," Czapar said.

Discovery Through Research

But not every problem is so easily identified and so quickly solved. Consequently, the project included a research component for finding practical ways to improve pesticide and nitrogen management, increase irrigation efficiency, and reduce soil erosion. Bill Simmons, a UI agronomist, is tackling these problems at the UI Sand Farm near Kilborne.

One practice that Simmons said appears particularly promising is split applications of nitrogen to minimize leaching after a rainfall. The benefit of having small amounts of nitrogen in the soil was especially evident during last summer's record-breaking rainfall.

The high potential for agricultural chemicals to move through sandy soils also makes herbicide product choice especially important in the area. To help farmers, Simmons is testing an array of products and product combinations that degrade rapidly or have low leaching potential; starch encapsulation and other herbicide formulations that promise less movement through soil; and postemergence weed control strategies.

He also is assessing cover crops, not just for protection of fragile sandy soils from wind and water erosion, but also for how they can help farmers use more environmentally friendly nitrogen and herbicide strategies. Corn planted into killed hairy vetch, for instance, appears to benefit from nitrogen produced by the cover crop. Rye has a grass-suppressing effect that could help growers move away from herbicides used prior to planting.

Simmons hosts farmers at the Sand Farm every year to share his findings. That the farmers are interested in what they see is reflected in their own fields.

"It's amazing how many fields have rye growing as a cover crop now," Whitaker said of his family's farm and those nearby. "And there seems to be a genuine interest in seeing the minimum level of herbicide and insecticide used, compared to the attitude I saw 20 years ago."

A rye cover crop is part of the cropping strategy on the Whitaker family farm, where harvests over the years have included wheat, corn, soybeans, popcorn, green beans, and hay. Other changes on the farm attest to the family's concern for protecting the farm's natural resources. Three old irrigation systems have new check valves. Pesticide and fertilizer use is kept to a minimum. Tillage also is kept to a minimum to reduce wind erosion and increase soil moisture in nonirrigated fields.

Popcorn producer and community activist Edward Whitaker takes to heart the quality of water in the Sankoty aquifer: "Farm families drink water from the aquifer. We want to farm so that water quality is preserved or improved."

Desktop Farming

Within a few years, the family might "farm" on a computer before going to the field. The keystroke approach to decision making may be possible through a computer model being developed by the SCS. The model predicts how irrigation scheduling, farming practices, and certain pesticide products might affect groundwater.

How Well Is Our Well Water?

The first statistically designed well-water sampling program conducted in Illinois has provided an estimate of the extent of pesticide and nitrate contamination in rural, private water-supply wells. Last November, the Illinois Department of Agriculture (IDOA), Illinois State Geological Survey (ISGS), and University of Illinois Cooperative Extension Service (UICES) released a joint report that projects:

- About 12 percent of the state's 360,000 rural, private wells may contain detectable concentrations of at least one pesticide or pesticide degradation product. Only about 2 percent of those detections are expected to exceed health-based guidelines for drinking water.
- Nearly 30 percent of rural wells may contain nitrate at levels greater than 3 parts per million (mg/L). This concentration frequently indicates contamination from sources such as nitrogen fertilizer, septic systems, or animal wastes. About 10 percent of the wells are expected to contain nitrate at levels exceeding the drinking-water standard of 10 mg/L.

The projections are based on a study begun three years ago in response to public concern over the potential for agricultural chemical contamination of groundwater. Initial efforts focused on inventorying the state to locate rural private wells and on gaining permission to sample the wells. From the pool of possibilities, 337 wells were randomly selected for the sampling program. On-site interviews, using forms and questionnaires, followed in an effort to gather detailed information on well sites, well construction, and activities and practices that might affect well water.

From March 1991 to April 1992, groundwater samples were collected once from each well and analyzed for nitrate, nitrite, and 38 pesticides and byproducts that form as pesticides degrade.

In the first report on the program, Warren Goetsch, IDOA, Dennis McKenna, formerly with the ISGS, and Tom Bicki, formerly with the UI, noted that half of the 38 pesticides chosen for analysis were not detected in any wells. Most of the other 19 detected pesticides were commonly used herbicides. Dinoseb, a herbicide no longer registered for use, was the most frequently detected pesticide.

Although no currently used insecticides were detected, aldrin, dieldrin, and endrin, along with the byproduct heptachlor epoxide, were present in some

The momentum behind change on the Whitaker farm and other farms is a result of a commitment to education built into the Illinois River Sands Water Quality Project.

Some efforts are aimed at bringing about immediate change. For instance, at an equipment calibration clinic last summer, Extension specialists used a computer to analyze the droplet pattern from an aerial application of red dye. The demonstration showed farmers the importance of measuring and fine-tuning equipment to spray pesticides more precisely.

Other programs, such as the Mason County Groundwater Protection Field Day, cosponsored by the project, are intended to increase awareness and knowledge of water as a manageable resource. The 1992 field day featured 25 speakers on topics ranging from water-monitoring surveys, to fuel storage, to well construction.

Young and Hopeful

With an eye to the future, some of the educational efforts are targeted to the next generation of land stewards. Kindergarten through sixth-grade students can learn about water quality from a curriculum developed through the project. Designed to fit state goals for learning, many of the activities can be worked into science, math, English, and spelling lesson plans.

The curriculum represents the best of more than 10 conservation courses used throughout the country, according to Mark Willi, Extension project assistant charged with presenting the materials to principals, teachers, and children.

"The materials are adapted to Illinois — our trees, soils, crops, and animals — to make the learning experience more real and more fun," said Willi, who estimated that he talked to more than 600 children about water quality last year. Models and other props add to the realism, allowing children to "do it, see it, taste it, and remember it."

To help teachers become part of the effort, the project cosponsored a two-day workshop on groundwater last summer. Every teacher received classroom instructional materials and built a groundwater model to take back to the classroom. The long, plexiglass aquarium filled with sand, gravel, clay, and other materials representing Mason County is interactive: add food coloring to simulate a fuel tank leak, and watch the effect.

"The model allows us to see on a small scale that what we do to the surface can flow miles away," Willi said. "We've made great strides with our generation, but environmental awareness could be second nature for these kids. The idea is to catch them at a young age — before they're even reading. It's got to help 20 years from now when they go out in the world and make decisions on whether to pollute or not."

Tina M. Prow, science writer, Agricultural Experiment Station ■

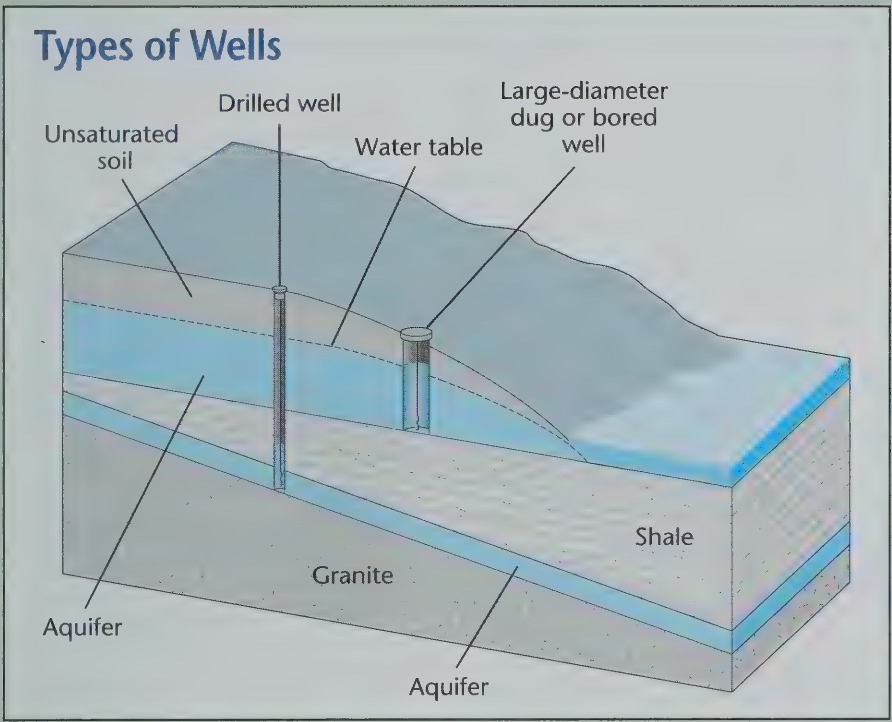


Illustration by M.R. Greenberg

well water samples. No longer registered, these insecticides were widely used in Illinois in the 1960s.

Data showed that concentrations greater than the health-based standards for drinking water were detected for dieldrin, heptachlor epoxide, and the herbicide alachlor.

An important factor in well-water contamination may be the wells themselves. Large-diameter dug or bored wells and shallow wells were more often contaminated with pesticides and nitrate than were drilled wells. Also, wells in areas where aquifers were within 20 feet of land surface were more likely to contain high levels of nitrate than were wells in areas where aquifers were farther from the land surface.

Details on this well-water sampling program can be found in "Statewide Survey for Agricultural Chemicals in Rural, Private Water-Supply Wells," available from the Bureau of Environmental Programs, IDOA, State Fairgrounds, Springfield, IL 62791. Additional reports are expected on well-water quality and agricultural chemical use, well construction, and factors affecting aquifer water quality. — *Tina M. Prow, science writer, Agricultural Experiment Station*

How Pesticides Move Through Soils

Pesticides play an important role in Illinois crop production, especially when used for controlling weed growth in corn and soybeans. But herbicides applied to the soil or to plant foliage may ultimately move beyond the soil surface and into water supplies.

How herbicides behave in the soil environment determines the likelihood of their eventual movement to groundwater. An ideal soil-applied herbicide would remain in the upper soil for a sufficient period of time to control germinating weeds and then would degrade into a harmless compound. If soil-applied herbicides degraded instantly in the soil environment, effective weed control would not be maintained.

Bill Simmons

Water is the primary vehicle for moving pesticides through soils. Researchers use dyes to help them visualize the leaching process.

The success of soil-applied herbicides depends on herbicide persistence and some water solubility to disperse the herbicide within the germination zone. Increasing persistence and water solubility is a double-edged sword, however — it helps control weeds but also creates the potential for groundwater contamination by increasing the likelihood that heavy rains may wash the herbicide through the soil.

Water is the primary vehicle for moving pesticides through soils. Most pesticides do not move freely with the wetting front following rain or irrigation the way nitrate nitrogen sometimes does. Pesticides have chemical properties that retard their movement through the soil by encouraging bonding with soil particles.

Soil properties have a strong effect on the likelihood and rate of pesticide movement in soils. Many herbicides are "hydrophobic" and therefore prefer to adsorb onto soil organic matter rather than be solubilized in water. Dark prairie soils that contain 4 to 5 percent organic matter are more successful at binding soil-applied herbicides than are sandy soils. The water-holding capacity is also greater in dark silt loam soils than in sandy soils. One inch of rainfall may penetrate 1 foot into a sandy soil, whereas the same rain on a silt loam soil may only wet the upper 3 inches below the soil surface. The combined effect of low organic matter and low water-holding capacity in sandy soils makes the potential depth of leaching five to ten times greater than in a dark silt loam.

Recent rural well water surveys suggest that groundwater contamination in these dark soils is less likely than in soils with low organic matter. Pesticides and water may move through soils in channels and pores under different rainfall and soil conditions. Staining dyes and tracer chemicals are used by researchers to study the patterns of pesticide movement.

Farmers' continued adoption of no-till and conservation tillage has raised questions about how the different soil properties affect the movement of water, nutrients, and pesticides. Reducing tillage increases the number of wormholes and other open pathways (called macropores) into and through the soil. Water infiltration rates typically increase when tillage is reduced. If a high-intensity rain directly follows pesticide application, the movement of water and pesticides through these holes may be quick and may "bypass" drier regions. This same bypass-flow phenomenon may be helpful in protecting groundwater quality if a gentle rain occurs after pesticide application. Under low rainfall rates, water and pesticides soak into the small pores in the soil much the way water is adsorbed into a sponge. Later rainfalls of greater intensity may flow down the macropores, bypassing the pesticide held in the smaller soil pores.

Soil properties are an important factor controlling pesticide movement. Considering soils, geology, well characteristics, and agronomic practices together will help establish the vulnerability of drinking-water supplies to contamination by pesticides.
— Bill Simmons, assistant professor of soil and water management, Department of Agronomy

A Legacy of Growth

Dr. Ben Jones, the retiring associate director of the Experiment Station, is not one to brag. Despite the high praise of his University of Illinois colleagues and national recognition from his peers, Jones insists that "the associate director shouldn't have any personal achievements. The AD is a part of a team and shares in that team's achievements."

This team-member mentality is just one of the qualities that others have appreciated during Jones' long tenure with the University. Jones' association with the UI began when he was an undergraduate in agricultural engineering. He received his B.S. in 1949 and his M.S. a year later. For two years afterward he was at the University of Vermont as an assistant professor and extension agricultural engineer, but in 1952 Jones returned to the UI as an instructor in agricultural engineering. He received his Ph.D. in civil engineering in 1958. At that time he was named associate professor and head of the soil and water mechanics division of the Agricultural Engineering Department. He was promoted to professor in 1964, and in 1973 he became associate director of the Illinois Agricultural Experiment Station.

Dr. Jones has been successful at the local, state, and national levels. He says some of his "points of satisfaction" were being part of the development of the Food for Century III proposal; helping to implement programs in environmental quality and biotechnology; strengthening programs in field research and nutritional science; and advising several commodity checkoff boards. He also helped develop the research and education titles of the last two Farm Bills and served four years on the Committee of Nine, one year as its chairperson.

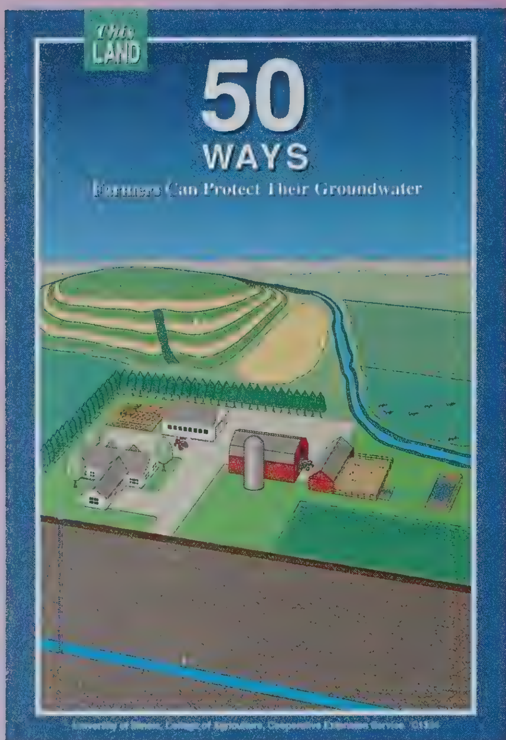
He is a fellow of the American Society of Agricultural Engineers and received its Hancor Soil and Water Award for "outstanding achievements as an engineering educator and research administrator and for dedicated service to ASAE."

The wide range of Dr. Jones' activities reflects what many colleagues see as his greatest strength: his vast body of knowledge. "To me, Ben is a library," says Bill George, director of academic programs and associate dean. "He has a catalog of information in his brain, and it's detailed, background information. I always felt comfortable going to him for advice — he could really put things in perspective."

Dr. Jones says that his basic philosophy was to "help the Station operate efficiently and effectively. The challenge lay in making it possible to implement plans by removing constraints." George adds that "Ben never read you the rules and regulations as to why you couldn't do something. He'd go out of his way to help you."

Cooperative Extension Service assistant director Peter Bloome believes that he is "uniquely qualified to say that Ben was also a supportive graduate research adviser — he served as the chairman of my Ph.D. committee way back when!" Despite his old ties to Jones, however, Bloome says that his fondest memories come from "recent years, when I've had the opportunity to work closely with him. Whenever I had a problem, I could sit down with him and cash in on his wisdom. I'm going to miss him." And so will all of us.
— Terri Stone, publications editor, Office of Agricultural Communications and Education

For More Information



New Book Provides Ideas to Cut Costs, Protect Groundwater

A fount of information on groundwater conservation is available in a new book by the University of Illinois Cooperative Extension Service, *50 Ways Farmers Can Protect Their Groundwater*. The book includes profiles of farmers who demonstrate that certain management practices can be both environmentally and economically sound:

- Michigan farmer Bill Hunt estimates that his crop scouting program saves him $8,000 annually and only costs from $1,000 to $2,000 per year.
- Illinois farmer Norm Larson has found that he does not sacrifice yields by cutting his insecticide applications to three-quarter rates.
- Indiana farmer Ted Macy estimates that he saved $25,000 in inputs during 1991 by using "site-specific" farming.

In addition to individual farmers' success stories, *50 Ways* also features research and management tips from UI specialists on ways to cut back on pesticides and fertilizer without cutting yields, ways to determine which pesticides are less likely to leach, and ways to apply chemicals more efficiently. It also includes sections on chemical storage, wells, septic systems, livestock waste management, irrigation, chemigation, water testing, and water treatment.

This colorfully illustrated book is available for $5. To receive a copy, send a check or money order to the following address, or call the phone number provided: Office of Agricultural Communications and Education, 69-IR Mumford Hall, 1301 W. Gregory Dr., Urbana, IL 61801, (217)333-2007.

Video Depicts Change in Karst Country

Most people know what sinkholes are, but few of us know that the geological term for sinkhole areas is *karst*. The karst country of southwestern Illinois is the focus of a new videotape that looks at what citizens in Monroe, Randolph, and St. Clair counties are doing to protect their groundwater.

Produced by the video unit of Information Services, Office of Agricultural Communications and Education, the video is titled "A Quiet Change in Illinois Karst Country." It highlights the Mississippi Karst Planning Committee, a group of concerned citizens and local governmental officials working together to bring "a quiet change" in attitudes and public awareness about the fragile karst environment in their region.

Monroe County is in the heart of karst country, which includes about 40 percent of the United States east of Tulsa. Because of its proximity to St. Louis, Monroe County is also one of the fastest growing areas in southern Illinois. With growth has come problems. At least 50 percent of rural wells in the area are in some way contaminated.

Mike Roegge, a Cooperative Extension Service educator who serves on the Karst Committee, is hopeful that the video, along with a general public awareness campaign, will increase the public's interest in groundwater protection and make them better informed.

Perhaps no one speaks so plainly about the urgency of the groundwater situation than Tom Aley, a nationally known karst expert who appears on the video. "I think a lot of people believe that we sort of live on an infinite filter," Aley says. "Not in a karst area. You don't live on an infinite filter, you live on a piece of Swiss cheese. There are holes all over. If we are to take care of groundwater quality in karst areas, we must take care of water quality on the surface."

VHS copies of the video are available through the University of Illinois Film Center, 1325 South Oak, Champaign, IL 61820. The toll-free telephone number is (800)367-3456.

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